Stratigraphy of the Paluxy River Tracksites in and around Dinosaur Valley State Park, Lower Cretaceous Glen Rose Formation, Somervell County, Texas.

Benjamin F. Dattilo
Indiana University - Purdue University Fort Wayne, dattilob@ipfw.edu

Sadye C. Howald
Indiana University - Purdue University Fort Wayne

Rena Bonem
Baylor University, Rena_Bonem@baylor.edu

James O. Farlow
Indiana University - Purdue University Fort Wayne, farlow@ipfw.edu

Anthony J. Martin
Emory University

See next page for additional authors

Author(s)
Benjamin F. Dattilo, Sadye C. Howald, Rena Bonem, James O. Farlow, Anthony J. Martin, Mike O'brien, Michael Blair, Glen Kuban, Lydia Mark, April R. Knox, William Ward, and Tara Joyce

Lockley, M.G. & Lucas, S.G., eds., 2014, Fossil footprints of western North America: NMMNHS Bulletin 62

STRATIGRAPHY OF THE PALUXY RIVER TRACKSITES IN AND AROUND DINOSAUR VALLEY STATE PARK, LOWER CRETACEOUS GLEN ROSE FORMATION, SOMERVELL COUNTY, TEXAS

BENJAMIN F. DATTILO[1], SADYE C. HOWALD[1], RENA BONEM[2], JAMES FARLOW[1], ANTHONY J MARTIN[3], MIKE O'BRIEN[4], MICHAEL G. BLAIR[1], GLEN KUBAN[5], LYDIA K. MARK[1], APRIL R. KNOX[1], WILLIAM N. WARD[1] AND TARA JOYCE[1]

[1]Department of Geosciences, Indiana University Purdue University Fort Wayne, 2101 East Coliseum Boulevard, Fort Wayne, Indiana 46805; [2]Department of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798; [3]Department of Environmental Studies, Emory University, Atlanta, Georgia 30322; [4]Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, TX; [5]4726 Grayton Rd, Cleveland, OH 44135

Abstract—The dinosaur tracks of the Glen Rose Formation in the Paluxy River at Dinosaur Valley State Park are among the best preserved and most abundant in the world. Although many tracksites are easily correlated to the Main Tracksite, others, especially those at the extreme ends of the park, are differently preserved and not obviously correlated. To count track horizons, several stratigraphic sections were measured along the river from upstream at the McFall Ledge Site to 7.6 km downstream at the County Road 1001 crossing (3.1 km linear distance). High-resolution correlation of these sections reveals that 6 meters of strata separate two track-bearing intervals exposed in the river. Seven distinctive beds can be correlated: 1) the lowest, the main track layer, a dolomitic mud with *Arenicolites* burrows and finely preserved footprints, 2) a hardground bed with oyster-encrusted bored cobbles, 3) the "steinkern marl," a fining upward shaly-concretionary unit containing a diverse fauna including clams and serpulid mounds in life position, 4) the "*Corbula* bed," a few cm of grainstone consisting almost exclusively of mm-size, diagenetically-altered articulated clam steinkerns, 5) the serpulid bed, a fine-grained packstone riddled with *Thalassinoides* burrow networks and occupied by sparsely-scattered meter-sized serpulid mounds, 6) the Taylor track layer, containing variably-preserved footprints and mudcracks and 7) the highest, the *Diplocraterion* bed, a wackestone ledge characterized by the U-shaped burrow *Diplocraterion*. High-resolution geologic maps showing the outcrop distribution of these stratigraphic units in the Paluxy Riverbed reveal patterns of local structural relief that expose the main track layer in the northern Park Central park area, and expose the higher Taylor track layer at the eastern and western/southern part of the park. These maps also serve as a guide to resource management in the Park, showing where erosion is destroying track layers and where the same erosion is uncovering new tracksites.

INTRODUCTION

Dinosaur Valley State Park (DVSP; Fig. 1), near Glen Rose, Texas, about 60 miles south of the Dallas-Fort Worth metroplex (Fig. 1A), contains many well-preserved dinosaur tracks, including arguably the best-preserved sauropod tracks in the world. These tracks, in the Lower Cretaceous Glen Rose Formation, are exposed in the bed of the Paluxy River.

Since the publication of the last stratigraphic correlations of the DVSP (Nagle, 1968; Pittman, 1989; Hawthorne, 1990), tracksite mapping and documentation have continued (e.g., Kuban, 1989a, b; Farlow et al., 2012). The purpose of these tracksite mapping studies is to understand the occurrence of dinosaur tracksites, to infer aspects of trackmaker biology and behavior, and to generate a complete catalogue of the tracksites in DVSP for resource management purposes. The stratigraphic context of these tracks is important for all of these aims. On the one hand, if two track sites occur at the same horizon stratigraphically, then it is possible that the same individual dinosaurs are represented therein, and that the same trackways can be traced from one site to another, giving a more accurate account of the population and a broader view of behavior. On the other hand, knowing where in the river bed a given track layer has been removed, and more importantly, where it is yet to be exposed by erosion, facilitates efficient monitoring and documentation of newly-exposed tracks, while also helping to focus documentation effort on tracks in eminent danger of erosional destruction.

This study serves to build on and revise previous stratigraphic work (Nagle, 1968; Pittman, 1989; Hawthorne, 1990) in and around the DVSP by confirming most correlations, offering alternate correlations in a few cases, and mapping these interpretations at high resolution. This work serves as a foundation for further research, particularly the sedimentology and diagenesis of specific horizons, and a sequence stratigraphic interpretation of the succession.

BACKGROUND

Stratigraphic Setting

The Lower Cretaceous (upper Aptian to Albian, Albian in the Glen Rose area) Glen Rose Formation (Fig. 2) overlies and interfingers to the northwest with the Bluff Dale Sand in the Glen Rose area. Both units comprise the Trinity Group (Rodgers, 1967; Hayward and Brown, 1967; Perkins, 1987). The sands and gravels of the Trinity Group unconformably overlie Paleozoic sedimentary rocks in the Glen Rose area. The Glen Rose is dominated by limestones, marls and shales, and is divided into a lower member (including the *Corbula* bed), the distinctive thick limestone marker Thorp Springs Member, and an upper member in the Glen Rose area. The Bluff Dale Sand represents a transgressive deposit (Hayward and Brown, 1967; Rogers, 1967; Perkins, 1987) and exhibits a facies transition relationship to the lower member of the Glen Rose (Nagle, 1968; Perkins, 1987). The age-equivalent Bluff Dale Sand facies replaces the lower member of the Glen Rose to the northwest near Paluxy, Texas.

To the southeast, in central Texas, the Glen Rose is thicker.

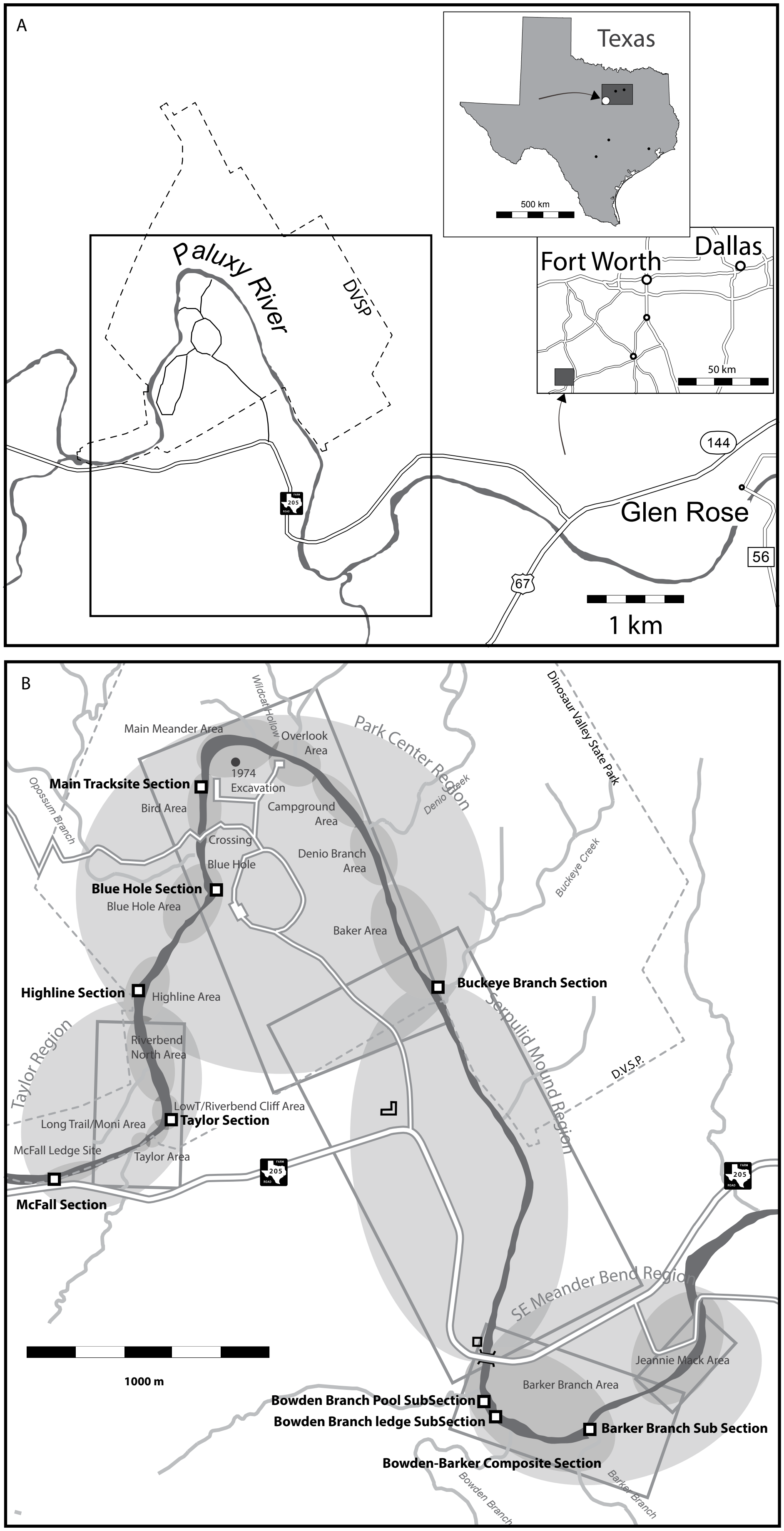

FIGURE 1. Locality map. **A**, Index map showing location of the study area. **B**, Detail of the study area showing the locations of measured sections and the “regions” and “areas” of the Paluxy River.

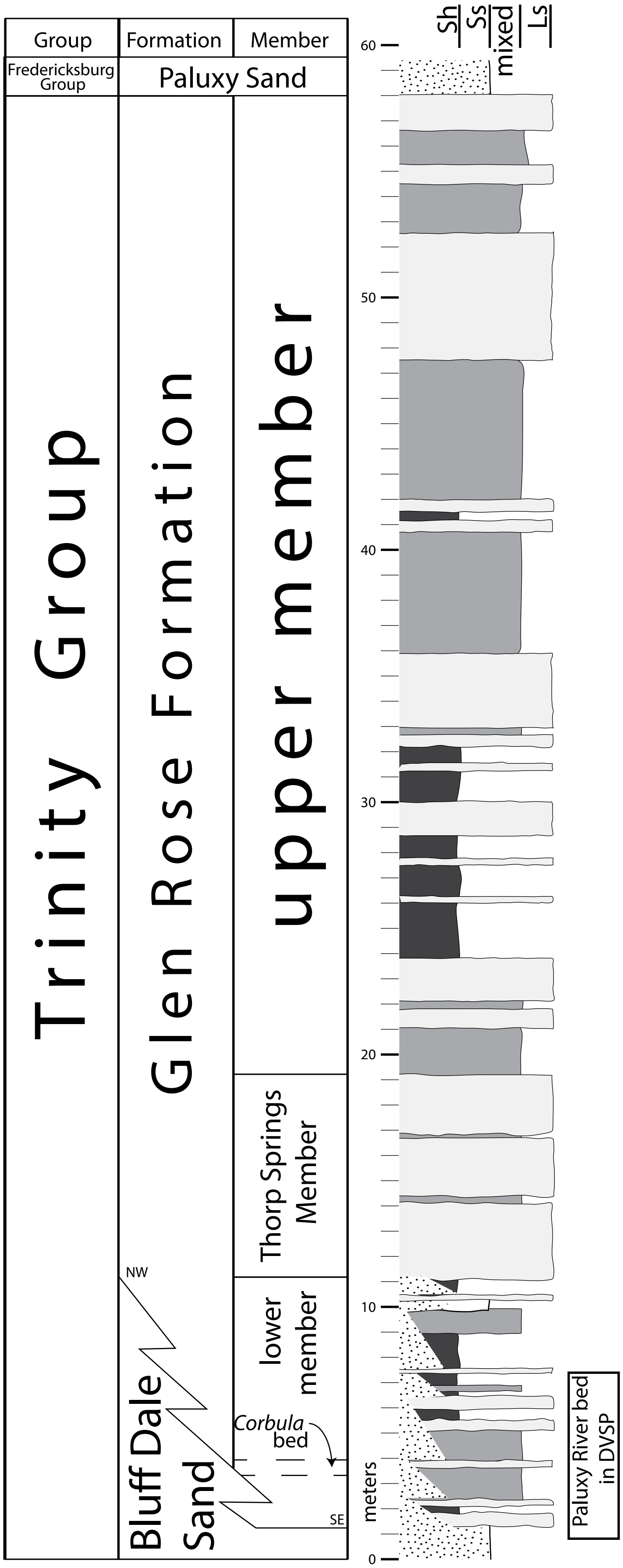

FIGURE 2. Stratigraphy of the Albian Glen Rose Formation between Paluxy and Glen Rose, Texas. The study interval is in the mixed carbonates of the lower member, which grades northwestward into the Bluff Dale Sand facies. The Bluff Dale Sand facies is restricted to the base of the section in Dinosaur Valley State Park. Based on Rodgers (1967, fig. 6) and Perkins (1987, fig. 7).

The Thorp Springs Member is not recognized, but the *Corbula* bed, presumably correlative with the *Corbula* bed at DVSP, forms a widespread interregional marker (Fig. 2). This convenient marker horizon defines the boundary between the Lower Glen Rose Member and the Upper Glen Rose Member, long used informally (e.g. Lozo and Stricklin, 1956; Hayward and Brown, 1967; Young 1967; Perkins, 1979; Hawthorne, 1990), and formalized by Scott et al. (2007). Thus, the formalized Lower Glen Rose Member in the southeast is not only much thinner in the Glen Rose region, but is not precisely correlative to the "lower member" of local usage. This landward thinning of the lower Glen Rose is consistent with transgressive onlapping, where the lower Glen Rose laps out to the north. The well-preserved dinosaur tracks in the DVSP indicate some of the earliest marginal marine Cretaceous facies in the immediate area.

Previous High-resolution Stratigraphic Work

Understanding the precise stratigraphic relationships among these tracksites began with the work of Rodgers (1967) and Nagle (1968), who established a roughly NE-SW striking facies trend, with paleoenvironments deepening to the southeast and shallowing to the northwest. Both Nagle (1968) and Hawthorne (1990) made detailed stratigraphic correlations along the Paluxy River through Dinosaur Valley State Park, and established important, informally-named marker beds (Fig. 3). These beds include the main track layer, the lower steinkern marl, the *Corbula* bed, the upper steinkern marl, the serpulid bed and (re-named in this paper) the serpulid shale, the Taylor track layer and the *Diplocraterion* bed. We include two additional beds above the *Diplocraterion* bed for correlation at the eastern end of the study area; these are the sandstone marker bed and the packstone marker bed. These units are discussed in detail below.

While Nagle (1968) recognized that trackways occurred in the main track layer, he did not observe that any trackways occurred at other horizons, and concentrated efforts on stratigraphic correlation and paleoenvironmental interpretation. Hawthorne (1990) both mapped trackways and reported on their stratigraphic occurrences; he reported four distinct track horizons within the immediate area of Dinosaur Valley State Park (Fig 3). These included the main track layer, the serpulid reef bed, the lower McFall layer (herein the Taylor track layer), and the upper McFall layer (i.e., the resistant bed; herein the *Diplocraterion* bed).

LOCALITIES AND METHODS

Scope

Both Nagle (1967) and Hawthorne (1990) reported on a relatively broad geographic and stratigraphic range of strata and tracksite occurrences. This report is restricted geographically to the stretch of the Paluxy River in the immediate vicinity of Dinosaur Valley State Park, between the McFall Ledge Tracksite and the County Road (CR) 1001 crossing tracksite (Fig. 1). It is stratigraphically restricted to those layers that are exposed in the bed and actively-eroding banks of the river over that stretch. Specifically, this means approximately 6 meters of section from the exposed upper Bluff Dale Sand to the *Diplocraterion* bed (Figs. 2-3), with an additional meter at the top of the Barker Branch Section to include the sandstone marker bed and the packstone marker bed.

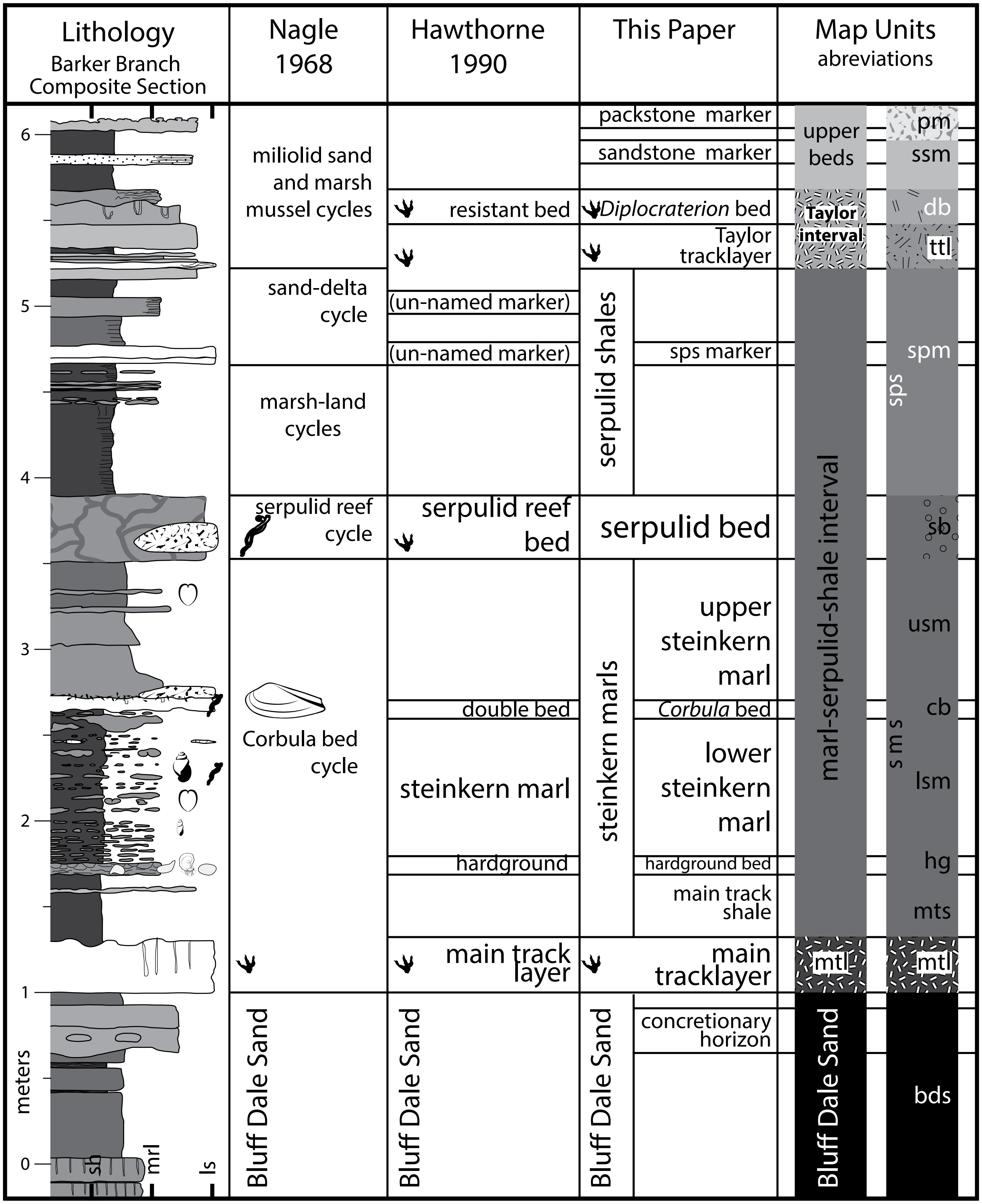

FIGURE 3. Barker Branch Composite Stratigraphic Section represents the mapped stratigraphic units. This diagram shows lithology and paleontology on the left, the stratigraphic nomenclature used in previous studies (Nagle, 1968 and Hawthorne, 1990), and the stratigraphic terminology used in this paper in the middle. The rightmost columns show map colors and patterns, and abbreviations used to indicate these strata in subsequent figures; the left column applies to low-resolution maps, the right column applies to high-resolution maps and labeled photographs.

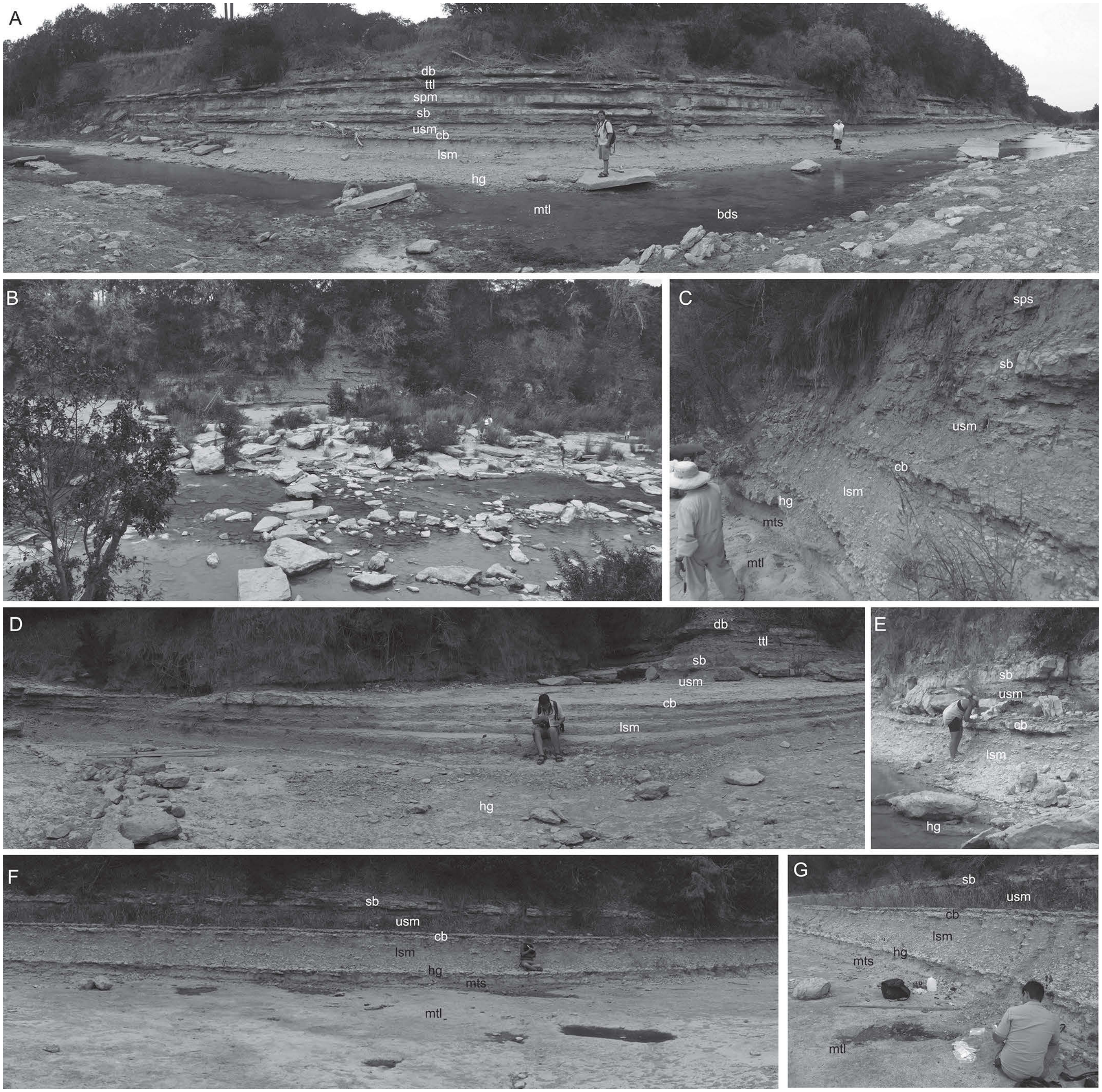

FIGURE 4. Selected measured stratigraphic sections along the Paluxy River. **A**, Highline section; **B, C,** Main Tracksite Section. **D, E,** Buckeye Branch Section. **F, G,** Bowden Branch Ledge SubSection, part of the Barker Branch Composite Section (Fig. 3). See Figure 3 for unit abbreviations.

Generally we rely on Nagle (1968), and we refine the stratigraphic trackway occurrences reported by Hawthorne (1990).

Fieldwork

Fieldwork in the Paluxy River was conducted one to two weeks at a time over three field seasons: 1) the summer of 2009, 2) the spring of 2011 and 3) the summer of 2012. In 2009, the river was particularly low and most tracksites (Farlow et al., 2012) and previously-documented stratigraphic sections (Nagle, 1968; Perkins, 1987; Hawthorne, 1990) were well exposed. We walked the entire river bed between the Mcfall Ledge Tracksite and the CR 1001 Crossing Tracksite. We documented all tracksite areas that we could recognize, recorded locations using GPS, took photographs, and wrote observations taking particular note of stratigraphic context and stratigraphic correlation from site to site. These observations were supplemented in later field seasons, with particular emphasis on difficult stratigraphic problems in the Taylor Region and Jeannie Mack Site and CR 1001 Crossing tracksites. The final field observation database contains more than 110 GPS-calibrated observation points along this 7.7 km stretch of riverbed.

While all stratigraphically valuable outcrops were described and photographed during this reconnaissance survey, seven outcrops were re-measured and described in high-resolution detail in order to document field correlations. Section measuring was accomplished by marking off 10 cm intervals temporarily with taped nails (for soft sediments) or “sidewalk chalk” (for indurated rocks). These marks were used as a guide in sketching beds down to just less than 1 cm thickness. Rock types and fossils were described using standard field techniques. Observations were chiefly made to accurately compare with previous work (Nagle, 1967; Hawthorne, 1990).

Sampling, particularly inside the park, was conservative and restricted by permit for this study. Stratinomic investigations are ongoing (see Farlow et al., 2012), but are not discussed here. Detailed observations of Nagle (1968) are generally sufficient. However, our lithologic description of the main track layer and the *Corbula* bed are informed in part by the optical and SEM/EDS study of thin sections made from samples collected in the field to help deduce the process of track formation, and to understand the diagenetic and taphonomic characteristics of a major interregional marker bed, respectively.

Geologic Mapping Technique

This paper presents preliminary bedding-scale geologic mapping of the river. Maps are based on the field observations and photographs supplemented by high-resolution Texas Orthoimagery Program USDA Farm Service Agency satellite imagery dated October 17, 2012 and freely available through Google Earth. Calibration of satellite images with precise field surveys suggests a parallax error of as much as 2 meters in the river bed. Thus, maps are not meant to convey precise locations or outlines of features, but illustrate, in detail, correlation of beds and the stratigraphic occurrences of tracksites.

Field GPS points were plotted in Google Earth, and bedding contacts were drawn on the satellite imagery with frequent reference to outcrop photos and notes. Images were saved as JPGs and contacts were traced in Adobe Illustrator to generate final high-resolution maps. Lower-resolution geologic map and stratigraphic cross sections were prepared with higher resolution maps as reference.

Tracksites and Stratigraphic Sections

Many tracksites (Farlow et al., 2012; Fig. 1 for examples) and their associated stratigraphic exposures (Nagle, 1968; Hawthorne, 1990) have been documented in the Paluxy River. For the purposes of discussion and mapping they are lumped geographically into “areas,” which are geographic clusters of related tracksites, and into “regions” which are geographic clusters of areas. Here we list these regions, areas, and their key sites and describe them, generally referring to previous work for more detailed descriptions. We have made an effort to cite multiple names and to include the names of smaller sites in the larger groupings.

The Taylor Region covers 1.17 km along the stream bed from the McFall Ledge Tracksite (starting at 32°14’12.87”N 97°49’37.35”W), through the Riverbend North Area.

McFall Ledge Site is separated from the Taylor Area by a gap of 240 m, and contains two track-bearing beds. The McFall Ledge Section (32°14’13.33”N 97°49’33.34”W) was measured on the cliff below the tracksite. Correlation of the track-bearing beds is discussed below.

The rest of the Taylor Region area are the Taylor Area (Kuban, 1989a,b), the Long Trail/ Moni Area, the LowT/Riverbend Cliff Area, and the Riverbend North Area (ending at 32°14’32.54”N 97°49’16.27”W), and the LowT/Riverbend Cliff Section (32°14’23.39”N 97°49’12.50”W).

The Highline Area starts at the poorly-documented Highline Tracksite (32°14’37.63”N 97°49’18.74”W), 175 m downstream through alluvium-covered riverbed from the Taylor area sites. It extends farther downstream to Hawthorne’s (1990) B.S. 6 Site (32°14’47.45”N 97°49’12.59”W), a distance of 360 meters. Most of the area is obscured with a cover of alluvium. The Highline Tracksite consists of a few isolated meter-scale exposures of track-bearing strata just west of powerlines that cross the stream at the bend, where erosion has exposed and breached more of the track-bearing layer around a deep meander-bend pool. The B.S. 6 tracksite and stratigraphic section (Hawthorne, 1990) is an isolated exposure of a few tracks that lies 320 meters downstream of the Highline site. Only a few tracks are there, but a small bank exposure provides stratigraphic context. This section was not measured, but used in walking correlations. The Highline Section (Fig. 4A) was measured in the cutbank exposure just under the powerlines over a distance of more than 150 meters.

The Park Center Region includes the tracksites found in the stretch of river directly accessible from currently public roads that radiate from the park’s loop road and campsite, as well as the emergent tracks downstream. Specifically, the region includes the Blue Hole Area, the Bird Area, the Overlook Area, the Campground Area, the Denio Area, and the emergent Baker Area.

The Blue Hole Area includes closely-related tracksites surrounding the Blue Hole and starts at the Blue Hole Ballroom and Parlor (Farlow et al., 2012; 32°14’51.13”N 97°49’10.04”W), 130 meters downstream, through a mostly alluvium-covered area from the B.S. 6 Site of the Highline Area, and runs 380 meters downstream beyond the Blue Hole Site to the mouth of Opossum Branch. The Blue Hole Site runs 80 meters along the eastern edge of the Blue Hole cutbank pool. The Blue Hole Ballroom contains some of the best-preserved tracks currently in the park. The cutbank on the east side of the Blue Hole exposes strata that were measured and reported as the Blue Hole Section (32°14’56.25”N, 97°49’5.17”W)

The Bird Area (or Main Tracksite Area) is named for R.T. Bird’s 1940 river-bed excavation (Bird, 1939, 1944, 1954, 1985; Farlow et al., 2012). The area begins at the mouth of Opossum Branch (32°15’1.96”N, 97°49’8.26”W) and runs 600 meters downstream to the other side of the large meander bend in the park (32°15’18.85”N 97°49’2.80”W). It includes the Opossum Branch Site, about 115 meters upstream into the Opossum Branch tributary stream in the bed of the stream at a sharp meander bend with a steep cutbank exposing Cenozoic sediments. Several tracks are exposed, and Farlow et al. (2012) documented this site. The Bird Sites are a series of spectacular tracksites that start 50 meters downstream (north) of the mouth of Opossum Branch at a small road crossing. They continue through the site of Bird’s 1940 excavation (Farlow et al., 2012) to the Main Tracksite. These Bird-associated Tracksites include the Bird Excavation and Bird Site West Bank and Bird Site East Bank (or “Ozark Trails”), the Main Tracksite (Park site #2), and southern sites situated around the crossings of the pipelines and road in the park. These are all easily connected visually and clearly represent remnants of the same layer removed by erosion in the intervening spaces (Farlow et al., 2012). They are, by definition, in the main track layer. Exposures of the same track layer immediately north of the Main Tracksite and around the Main Meander Bend are now too deeply abraded to preserve many tracks. A 1974 Test Excavation was made in the flat area above the river bed into a track- bearing horizon to expose a

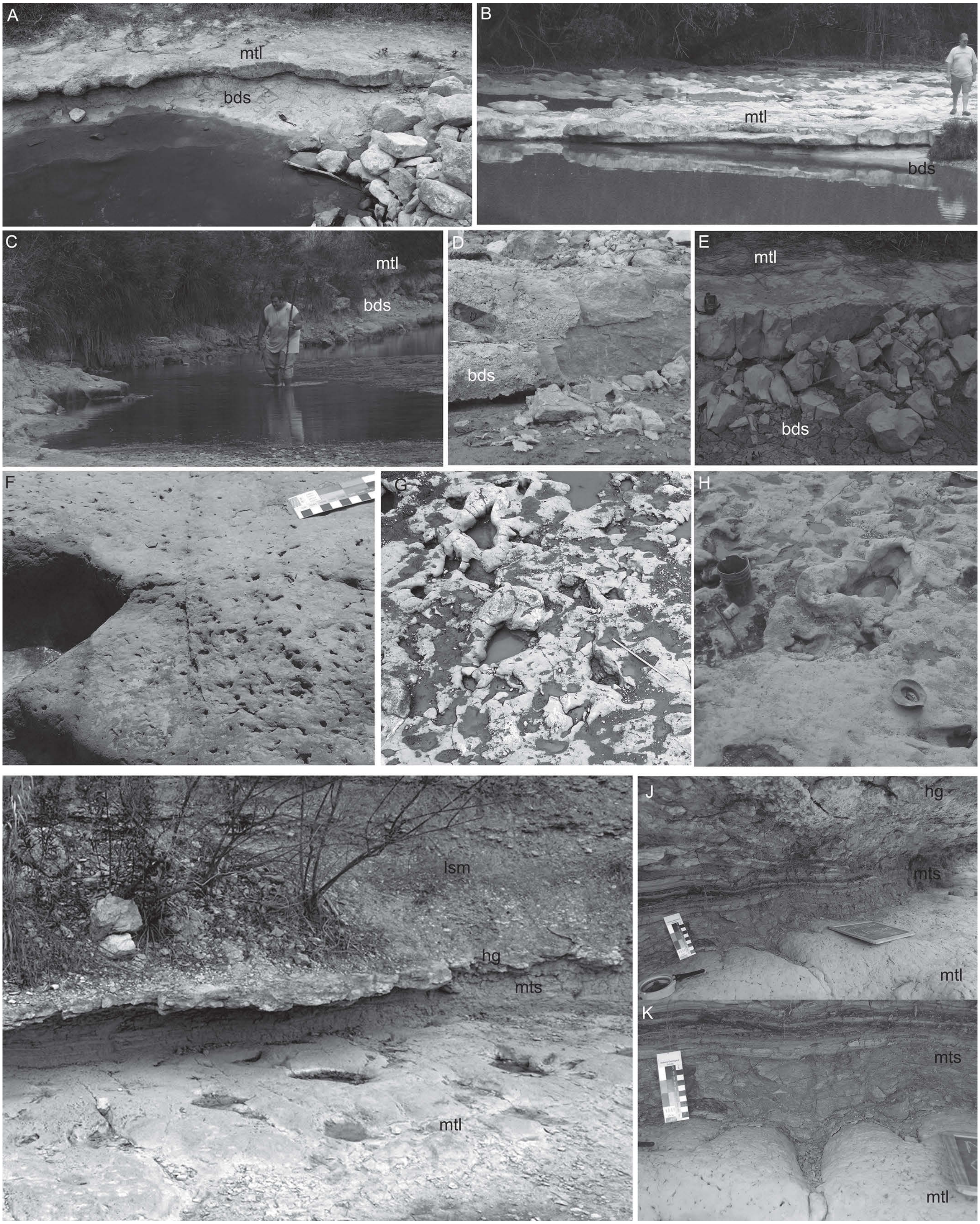

FIGURE 5. Field photos of the Bluff Dale Sand, main track layer and main track shale. **A, B**, Bluff Dale Sand and main track layer at the Main Meander Bend (A, Loc 273) and the Blue Hole Falls (B). **C, D**, Bluff Dale Sand exposed above the cutbank pool upstream from Bowden Branch, showing about a meter of bedded section (C), and a close-up view of one of the more indurated beds (D). **E**, Erosional removal of Bluff Dale Sand and undermining collapse of main track layer upstream from the Bird Site . **F**, Surface expression of burrows in main track layer at the Bird Site. **G, H**, Theropod and sauropod tracks in the Blue Hole Ballroom Tracksite showing the fine preservation of push-up structures (pressure ridges). **I-K**, Main track shale (recessive) at the freshly excavated area of the Main Tracksite , with closer views (J, K) of depositional laminae and relative lack of bioturbation over a partially uncovered theropod print. See Figure 3 for unit abbreviations.

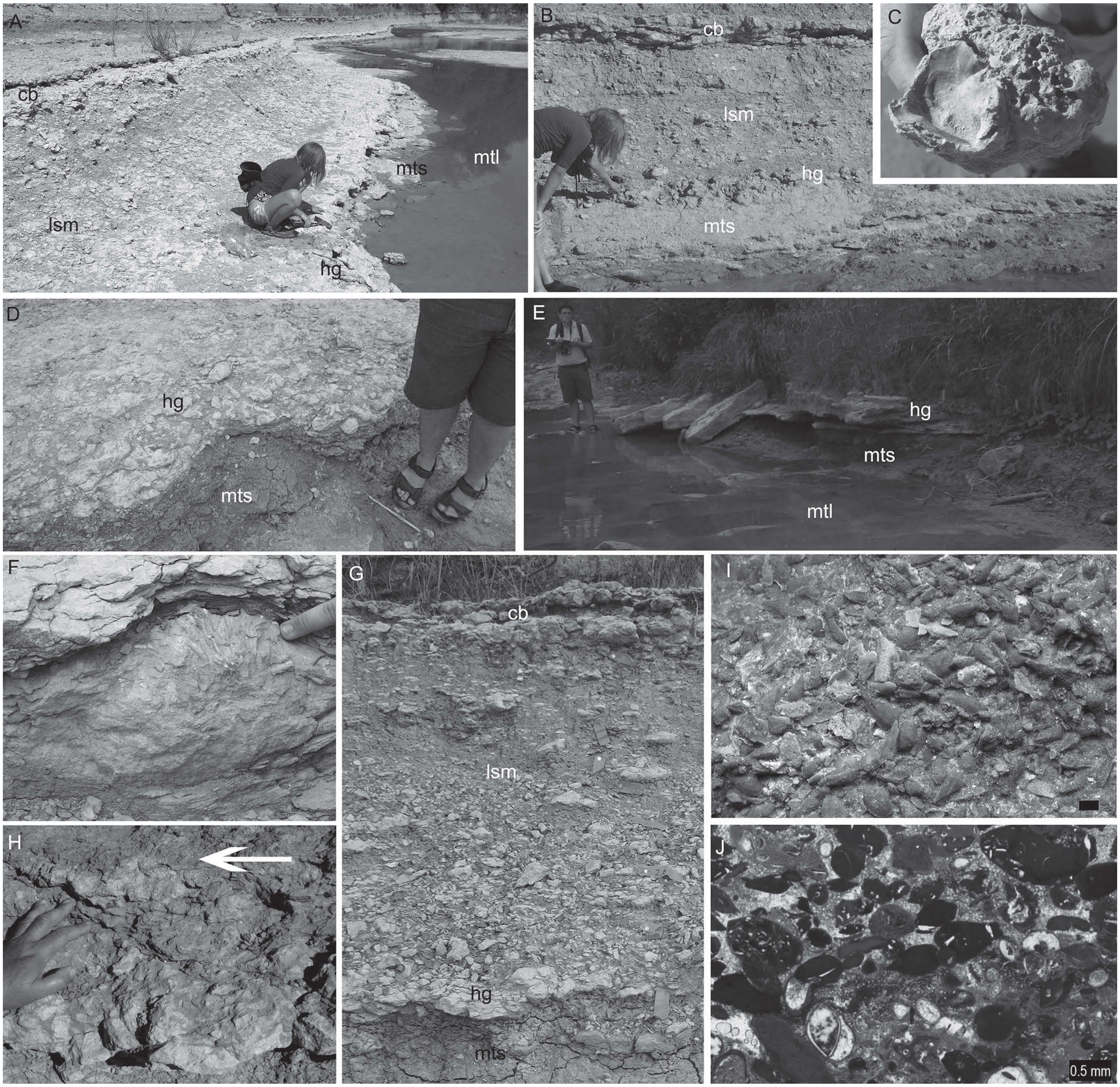

FIGURE 6. Photographs of the hardground bed, lower steinkern marl, and *Corbula* bed. **A,** Lower steinkern marl at Bowden Branch Section with distinct shelf at the hardground bed (lower) and at the *Cobula* bed (upper). **B, C,** The lower steinkern marl with hardground bed at the Highline Section (B), showing abundant bored cobbles (C). **D**, The hardground bed in the Denio Branch Section (loc. 284) is rubbly. **E**, The hardground bed at the Bird Tracksite West Bank (Loc. 270) is a thick ledge. **F**, Small serpulid mound from the lower steinkern marl in the Buckeye Branch Section (Loc. 295) **G**, Close view of the lower steinkern marl at the Bowden Branch Section showing rubbly concretionary texture. **H-J**, *Corbula* bed at Highline Section showing “double bed” of *Thalassinoides* –rich silty marly calcarenite (H), draped by thin lag (arrow) of mostly *Corbula* steinkerns (I, scale bar is 1 mm), which are filled with brown micrite as shown in thin section (J, scale bar = 0.5 mm). See Figure 3 for unit abbreviations.

roughly rectangular area 12 meters long and 4 meters wide approximately 120 meters ENE (80 deg) of the northeast corner of the Main Tracksite. Stratigraphic exposures in the Bird Area include a small exposure at the Main Tracksite, measured as the Main Tracksite Section (Fig. 4B, C; 32°15’11.67”N, 97°49’7.78”W). Additional exposures occur along the cutbank in the sharpest point of the Main Meander Bend and include Nagle’s (1967) Section SV-2 (32°15’17.86”N, 97°49’6.60”W), which was not measured.

The Overlook Area begins at the end of the Main Meander Bend, and includes the Overlook Site (Park Site 1), which is 480 meters downstream from the downstream end of the Main Tracksite, and 220 m NW (64 deg) from the 1974 excavation. This site has now mostly been eroded away (but footprints were seen here in previous years; Farlow, 1987), and consists of a remnant along the southern, inside bank of the large river bend. Similarly, the bordering Campground Area has been largely removed by erosion. The bank of the Overlook Site includes a clean stratigraphic exposure, the Overlook Section (32°15’16.16”N, 97°48’54.06”W), which was not measured, but used for correlation.

The Denio Branch Tracksite (32°15’1.25”N, 97°48’36.93”W) and Area is 215 meters downstream from the southernmost remnant of the Campground Tracksites, and about 30 meters long, ending about 920 meters downstream from the beginning of the Overlook Site. It is a mini-cuesta-like stream exposure dipping under overlying beds downstream and being eroded from its upstream edge. Farlow et al. (2012) document this site in detail. The Denio Section (SV-1 of Nagle 1968) starts at the southern end of the Denio Branch Tracksite on the west bank of the river and runs southward 140 meters.

The Baker Area runs from the end of Denio Branch to the end of the Buckeye Branch Stratigraphic Section (32°14’35.60”N, 97°48’23.34”W), a distance of 870 meters. This area includes a few emerging (i.e., in the process of being exposed by erosion) tracksites. An emergent Baker North Tracksite (32°14’50.80”N, 97°48’32.66”W) 380 meters downstream from the Denio Branch Site consists of a few tracks exposed by erosion in a small structural swell as a very small patch a few meters across. The Baker Site (32°14’45.27”N , 97°48’29.81”W) is 165 meters downstream from the Baker North Site, is about 18 meters long, and appears to be another swell, this time a synclinal looking structure with an apparent East-West trend, slightly breached at the center with several tracks exposed. Two small exposures, Buckeye Branch North and Buckeye Branch West, each a few meters across with a few tracks exposed, lie in another swell 100 meters downstream (south) of the Baker Site, and about 95 meters north of the mouth of Buckeye Branch, where the Buckeye Branch Section (Fig. 4D-E; 32°14’41.89”N, 97°48’26.22”W) was measured.

No tracks have been documented in the Serpulid Mound Region. This region extends from the south end of the Baker Area to approximately the Farm to Market Road 205 Bridge, (near the current site of the Creation Evidence Museum), a distance of 1.63 km. As discussed below, the lack of tracksites is mostly a function of which stratigraphic levels are exposed in this area. The area is rich in large serpulid mounds.

The Southeastern Meander Bend Region includes the Barker Branch Area and the Jeannie Mack Area. This region is separated 1.6 km along the river from other tracksites by the Serpulid Mound Region. It trends from the FM 205 Bridge to the County Road 1001 Crossing Tracksite (32°13’53.89”N, 97°47’40.53”W), a distance of 1.57 km.

The Barker Branch Area includes the Al West (or Bowden Branch) Tracksite, which is 2 km downstream of the Buckeye Branch Tracksite and well outside of park boundaries. Here, the track-bearing layer is preserved as a ledge along a deep cutbank pool just upstream of the site, and the site, with nicely exposed tracks, begins as a ledge along the downstream end of the pool. Tracks are exposed intermittently for about 85 meters along the streambed, being buried in alluvium and slightly younger Cretaceous rock about 25 meters upstream to the mouth of the Bowden Branch tributary. Kuban (1989a) mapped this tracksite. The Barker Branch Tracksite is first reported in this paper. This new tracksite is about 80 meters up the tributary. Tracks appear to be distributed in two layers.

The mouth of Barker Branch has been the upper part of a standard composite stratigraphic section for the track-bearing interval of the Paluxy River (e.g., Rodgers, 1967; Nagle, 1968; Perkins, 1987; Langston and Pittman, 1987; Hawthorne, 1990). This traditional section starts 380 meters upstream at the Al West Tracksite near the mouth of Bowden Branch (Fig. 4F-G). The Barker Branch Composite Section (Fig. 3) is the key stratigraphic reference section for this study.

The Jeannie Mack Area includes the Jeannie Mack (Lancaster Ranch) Tracksite, and the County Road 1001 Crossing Tracksite. The Jeannie Mack Tracksite is about 450 meters downstream from the mouth of the Barker Branch tributary, and is 120 meters long. This site was studied by Halbert (1967) and by Hawthorne (1990). The County Road 1001 Crossing Tracksite is 240 meters downstream from the downstream end of the Jeannie Mack Tracksite. It is an exposure of tracks in more than one horizon over 30 cm of stratigraphic thickness. It is exposed in a falls so the exposure crosses the entire width of the stream diagonally but is only a few meters “long.”

BEDS AND OTHER STRATIGRAPHIC UNITS

The stratigraphic column in Figure 3 illustrates the beds and other units correlated in this study and includes a synonymy table for comparing previous work (Nagle, 1968; Hawthorne, 1990). We describe each bed or interval so that it can be recognized in the field and in satellite imagery. Emphasis is on field observations of lithology and geomorphic expression, noting unique characteristics that help with identification, and reserving much interpretation of depositional process and paleoenvironment for other studies in progress.

Bluff Dale Sand

The Bluff Dale Sand (Fig. 5A-C) is an unconsolidated to slightly indurated very fine quartz sand and silt. It has an almost clay-like plasticity, but contains very little clay, and is greenish gray and easily eroded. It is not exposed significantly above water lever in DVSP and forms deep pools (e.g. Blue Hole, Fig. 5B). Once exposed by breaching of the main track layer, it tends to erode away and undermine the main track layer, which leads to collapse of the track layer (Fig. 5E). There are several partially indurated layers in the Bluff Dale Sand (Fig. 5D). The indurated layer that is often found about 10 cm below the base of the main track layer is of particular interest because, as discussed below, it tends to form the riverbed immediately after the main track layer has been removed by erosion, and can mimic somewhat the appearance of the main track layer. It tends to be softer and have a more irregular surface than the main track layer.

Main Track Layer and Main Track Shale

Hawthorne (1990) recognized the main track layer as having the most abundant and best preserved tracks in the bed of the Paluxy River in Dinosaur Valley State Park. This 10-30 cm thick layer is generally light buff in color and is made of a moderately cemented sandy dolomite with a uniform grain size in the very fine sand silt range. SEM/EDS analysis shows that this is mixed with small amounts of quartz and feldspar with very little clay. The bed lacks internal partings or discontinuities, and contains a little more sand within the basal few centimeters in direct contact with the Bluff Dale Sand. Vertical fractures dominate and tend to break the entire thickness of the bed into equant blocks (10-30 cm across; Fig. 5E). The upper surface of the bed is smooth and uninterrupted but riddled with small (<5 mm) holes (Fig. 5F) that indicate openings of vertically-oriented *Arenicolites* burrows (incorrectly identified as *Skolithos* by Farlow et al., 2012), whose formation may have contributed to the vertical uniformity of structure and the dominant vertical fracture pattern.

The tracks in this bed are deep with well-developed push-up structures (Fig. 5G-H) that suggest at least a brief period of time when the unconsolidated sediment was soft with a mud-like plastic consistency. A few slabbed tracks clearly show that dinosaur tracks were disrupted, and therefore formed after *Arenicolites* burrows (Farlow et al., 2012). In some cases, dinosaur tracks are surrounded by fractures that indicate firmground breakage along lines of weakness created by burrows.

Hawthorne (1990) described the bed directly overlying the track layer as "a thin gray green unfossiliferous shale." This "main track shale" (Figs. 5I-K) is clearly laminated, and lacks obvious evidence of bioturbation. It is found consistently over the main track layer in the study area, and its deposition is probably key to track preservation.

The Steinkern Marls

The beds within the interval between the main track shale and the serpulid bed are lumped together as the "steinkern marls" (Fig. 3). This is a series of distinctive beds and intervals whose predictable succession serves to constrain correlations of individual beds.

The first of these beds, the hardground bed, is an example of a traceable unit that is variably developed, presumably because the same bed formed under different environmental conditions. It is sandwiched between the main track shale and the lower steinkern marl, both of which are uniformly developed and bounded by very distinctive beds. In some places, mostly to the south, it consists of very indurated cobbles (Fig. 6A-D; Nagle, 1968). These cobbles are not only very hard, but also show evidence of synsedimentary cementation, in that they are commonly bored and encrusted by oysters and serpulids (e.g. Fig. 6C). To the north, for example in the Bird Area, this interval forms a solidly indurated layer up to 25 cm thick (Fig. 6E; Hawthorne, 1990).

The lower steinkern marl (or simply the steinkern marl of Nagle, 1968; Fig. 6A,B,F,G), while exhibiting some changes in fossil content (Nagle, 1968), is easily recognizable across the entire studied length of the riverbed. It generally forms a slope which is bounded by small ledges: the hardground bed at the bottom and the *Corbula* bed at the top (Fig. 6A,B,G). The bluish-gray interval is rubbly in appearance, with thin beds of uneven or concretionary silty marl intercalated with thin uneven beds of silty shale. The unit is abundantly fossiliferous, yielding marly steinkerns of large infaunal clams and a few varieties of snails, along with 5-10 cm serpulid mounds encrusting various other fossils, among other fossils. Although this is a nearshore assemblage it is fully marine, and represents the deepest subtidal environment in the succession.

The upper boundary of the lower steinkern marl is the *Corbula* bed (Nagle 1968) or the "double bed" of Hawthorne (1990). Next perhaps to the main track layer, the *Corbula* bed is the most consistently recognizable stratum in the area. From a distance it is recognized as a "double bed" (Hawthorne, 1990): two closely-spaced resistant ledges. These ledges are two more bluish-gray limestone-rich zones separated by a brown-to-buff shalier bed, all within 10-20 centimeters of thickness. The interval is riddled with *Thalassinoides* burrow networks. This is capped with the *Corbula* bed proper (arrow in Fig 6H-J), which is an accumulation as much as 1 cm thick of 1-2 mm "*Corbula*" steinkerns (the bivalve has since been reassigned to *Eoursivivas harveyi*: Scott, 2007) with minor amounts of serpulids and snails. SEM/EDS analysis suggests that the steinkerns, despite their odd brown color, are made of micrite. A few 10-30 cm serpulid mounds can be found on the upper surface of the *Corbula* bed.

The upper steinkern marl (Fig. 7A-D,G) is not as uniformly characterized as are the lower steinkern marl and surrounding intervals, but like the hardground bed, its upper and lower boundaries are clearly correlated. It is generally a calcareous shale containing three uneven concretionary marl beds. The unit is more terrigenous to the northwest (Fig. 7A), where marine fossils are rare at best, and is more marly to the southeast (Fig. 7B) where the rare steinkerns of large burrowing clams (Fig. 7C) can be found in life position.

The Serpulid Bed

The serpulid bed (Fig. 7A-B,D-I) is recognizable across the park for its 15 to 30 cm thickness and its pervasive penetration by *Thalassinoides* galleries. It is low in terrigenous sediment, massive and isotropic, and does not easily fracture. The weathered surface tends to have a porous appearance and it develops deep rills that run stream parallel. The large serpulid mounds for which it is best known (Nagle, 1968; Curtis, 1988; Hawthorne, 1990) are only developed on the east side of the park downstream from the Denio Branch Tracksite, where the serpulid bed is also thicker. They are generally "rooted" or start near the base of the bed but are commonly large enough to emerge from the top of the bed.

Above the serpulid bed is the serpulid shale interval (Fig. 7A), which was variably developed and as well exposed throughout the riverbed in the study area as lower or higher beds in the succession. It is generally shaly (e.g., Fig. 3), with one or two more indurated carbonate beds, one of which thickens markedly to the northwest (labeled "spm" in Fig. 7A), some of which are helpful in correlating, especially in the east.

The Taylor Track layer and *Diplocraterion* Bed

The Taylor track layer and *Diplocraterion* bed (Fig. 8) occur within 40 cm of each other throughout the study interval, and they crop out together as a cluster of ledges at the McFall Ledge Tracksite (Fig. 8A-D), at the Taylor Tracksite (Figs. 8E-F), and at the LowT/Riverbend Cliff Sites (Fig. 8G-K). Several lines of evidence suggest that the track-bearing layer at the Taylor and LowT/Riverbend Cliff Tracksites, dubbed the "Taylor track layer," is not the

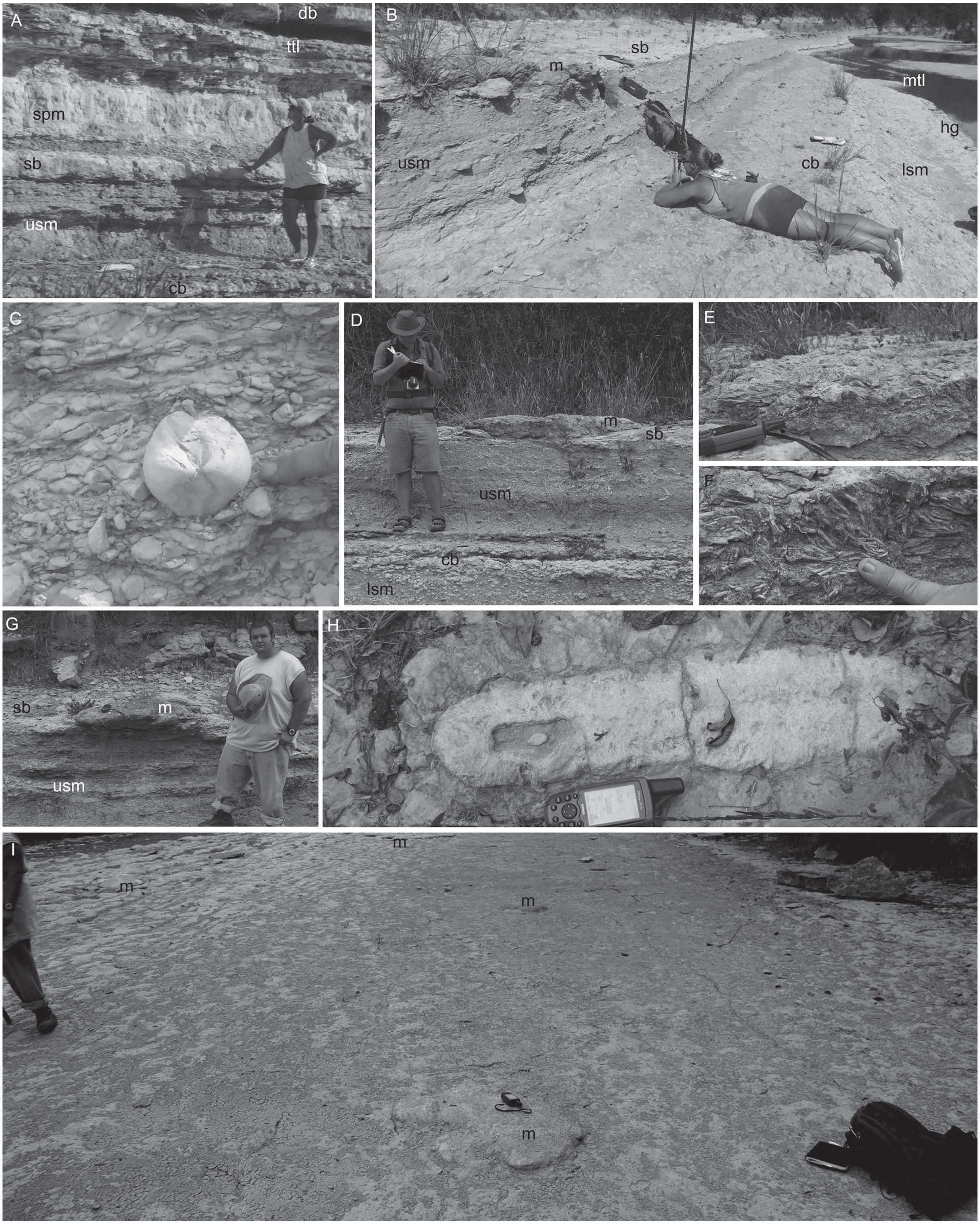

FIGURE 7. Outcrop photographs of the upper steinkern marl and serpulid bed. **A**, The interval from the *Corbula* bed to the *Diplocraterion* bed at the Highline Section. **B**, Interval between the *Corbula* bed and the serpulid bed at the Bowden Branch Section (Loc. 326), which contains a serpulid mound (m, see also D - F). **C**, Isolated large clam steinkern from the upper steinkern marl near the Bowden Branch Section. **D, E, F,** Progressively closer views of mound (m) shown in (B). **G**, Large serpulid mound in the serpulid bed south of the Buckeye Branch Section (Loc. 313). **H**, Elongate serpulid mound apparently encrusting a fossilized log (Loc. 322) just north of the FM 205 Bridge (Third Crossing). **I**, Serpulid bed with scattered serpulid mounds (m) exposed in river bed (Loc. 316). See Figure 3 for unit abbreviations.

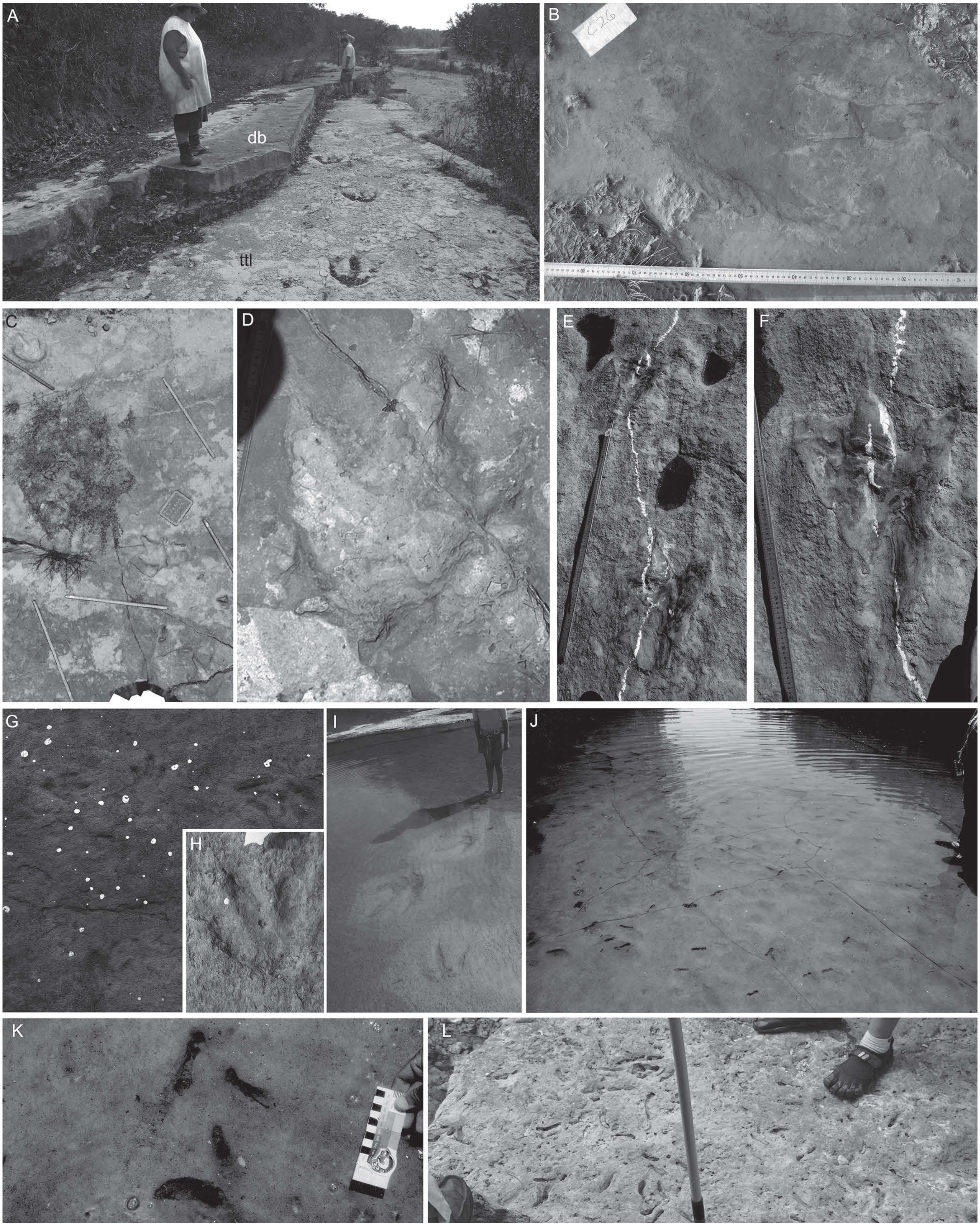

FIGURE 8. Outcrop photographs of the Taylor track layer and *Diplocraterion* bed. **A**, The McFall Ledge Tracksite showing the Taylor track layer with trackway and the *Diplocraterion* Bed (man standing in foreground, Loc. 309). **B**, Single track (directed toward the right) from the Taylor track layer surface at the McFall Ledge Site. **C**, McFall Ledge Trackway in the *Diplocraterion* bed. **D**, Single *Diplocraterion* bed footprint. **E,F,** Views of elongate "colored" footprints from near the Taylor Tracksite, Taylor track layer. **G, H**, Trackways and track from the LowT/Riverbend Cliff Area. **I**, Footprints in ripple marked surface in the Taylor track layer in the LowT/Riverbend Cliff Area. **J,K,** *Diplocraterion*-covered surface of the *Diplocraterion* bed in the LowT/Riverbend Cliff Area. **L**, Densely-burrowed surface of the *Diplocraterion* bed at the mouth of Buckeye Branch. See Figure 3 for unit abbreviations.

same as and does not correlate to the main track layer.

First, it has different visible characteristics. For one, the surface is complex, locally crumbly (Fig. 8A), elsewhere smooth, but not perforated by *Arenicolites* as in the main track layer. Aside from the paucity of sauropod tracks, tracks are not always preserved as simple impressions in the mud like in the main track layer, but in places are track impressions, and elsewhere are infilled with preferentially indurated sediments, which tend to turn orange after long exposure at and near the Taylor Tracksite (Fig. 8E-F). In some places the layer appears to be composed of sub-beds only a few cm thick, which suggests the possibility of a complex zone of tracks rather than a single horizon, and a complex thinly laminated bed (as seen in stratigraphic view, Fig. 7A near top), rather than a massive, thoroughly bioturbated one like the main track layer. These surfaces also contain mudcracks or microripples (Fig. 8I) along with dinosaur tracks, which are not seen in the main track layer.

The *Diplocraterion* bed forms the most resistant bed in the succession, and in many places is often the last remnant of Cretaceous rock beneath a Cenozoic unconformity (Figs. 4A, 7A). It is a packstone whose hardness is matched only by the hardground bed where fully indurated. At the McFall Ledge Tracksite the *Diplocraterion* bed bears dinosaur tracks, but it is most easily recognized by its abundant *Diplocraterion* ("U-tube") trace fossils (Fig. 8J-L). Both the Taylor track layer and the *Diplocraterion* bed figure heavily in the correlation to the Jeannie Mack and CR 1001 Crossing tracksites.

CORRELATIONS

We explain the process of correlation in detail by discussing each tracksite area and stratigraphic exposure from the McFall Section downstream through the park to the County Road 1001 Tracksite. In this discussion, the "right" or "left" bank of the river is right or left relative to the downstream direction, which is generally in the dip direction and up section. The details of correlation are summarized in five preliminary high-resolution geologic maps of the stream bed. The first three are: 1) the Taylor Region, 2) the Park Center Region and 3) the Serpulid Mound Region. The Southeast Meander Bend Region is divided into two additional maps: 4) the Barker Branch Area and 5) the Jeannie Mack Area. We supplement each map with a discussion of correlation through strategically placed field photographs and satellite imagery. The Highline Area is not fully mapped at the edges of either the Taylor Region map or the Park Center Region map, but we do discuss outcrop photographs and satellite imagery for this area.

Map 1: The Taylor Region

Map 1, the Taylor Region (Fig. 9), covers the McFall Ledge Site and the Taylor, LongTrail/Moni, LowT/Riverbend Cliff and Riverbend North Areas. The McFall Ledge Tracksite is some distance from the next outcrop and from the next tracksite, but there is a significant section exposed by stream erosion on the cliff below, so the position of the trackways is well constrained vertically and included in the measured section. This section starts in the lowest part of the stream bed where some bored cobbles occur, indicating that the upper part of the hardground bed is exposed here. It continues through the fossiliferous lower steinkern marl, the less fossil rich upper steinkern marl, the serpulid bed and a relatively sandy serpulid shale before reaching the lower track-bearing horizon on the ledge. This stratigraphic context constrains the ledge to near the Taylor Trackbed. The upper track-bearing horizon is a solid packstone with abundant *Diplocraterion* (Fig. 8C), easily identifiable as the *Diplocraterion* bed.

In the LowT/Riverbend Cliff Tracksites, it is clear that that there is one track-bearing bed, if not precisely one track-bearing surface. Beds within the area can be easily correlated from one site to another at ground level. Just east of the Taylor-associated sites, the *Diplocraterion* bed forms a solid channel-rim shelf (Fig. 10A-

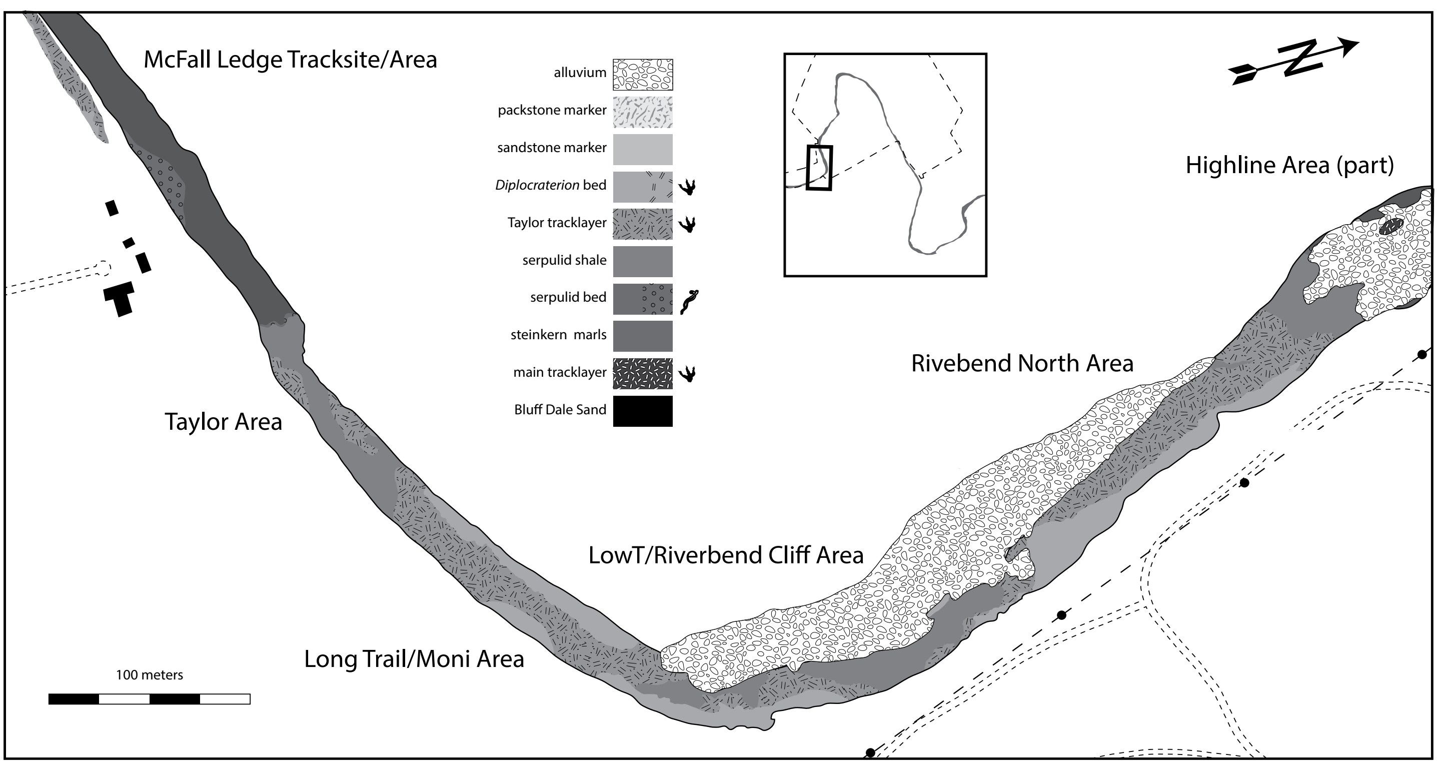

FIGURE 9. Preliminary Geologic Map of the Taylor Region, between the McFall Ledge Tracksite/Area and the Highline Area.

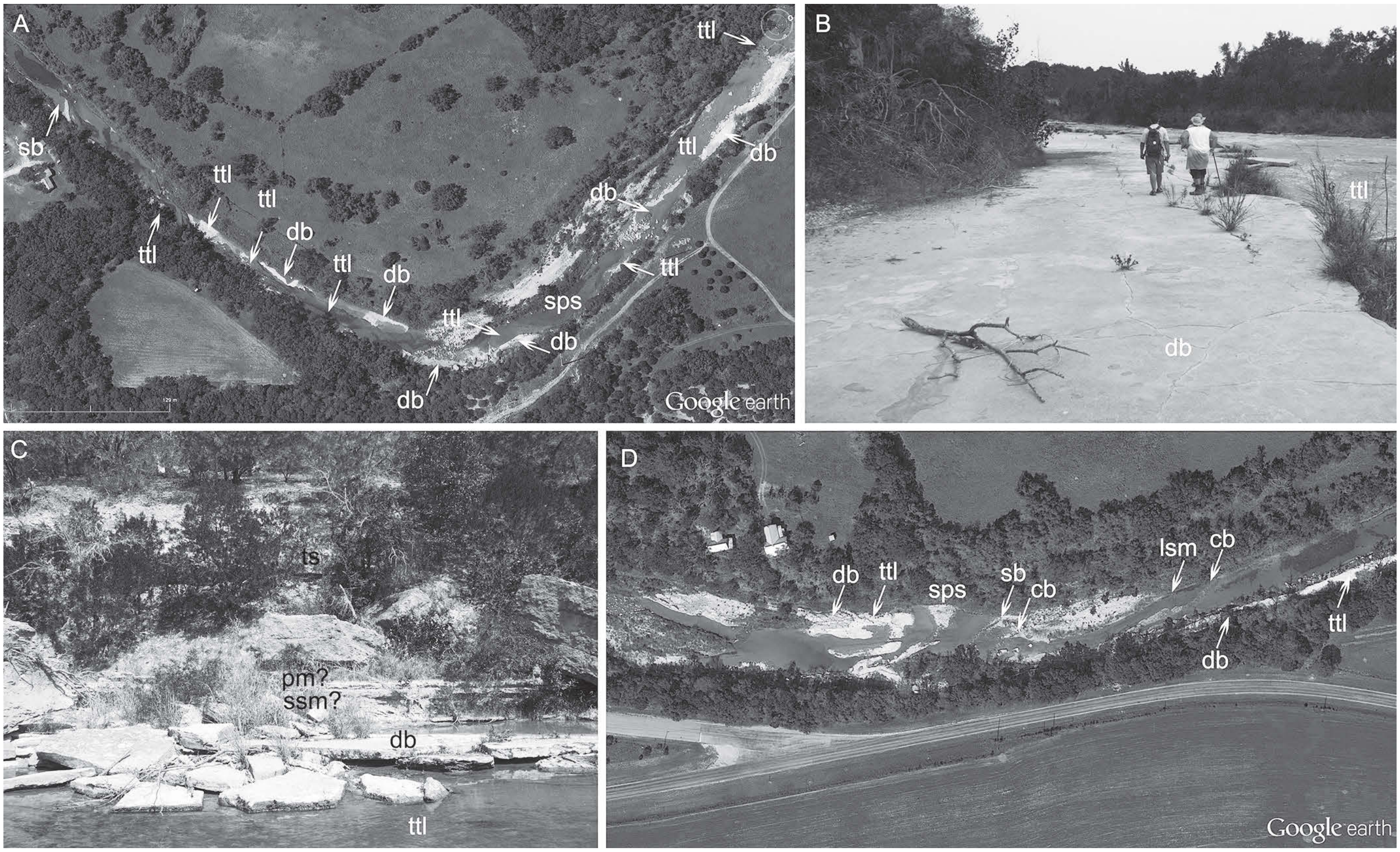

FIGURE 10. Photographs of the Taylor Region. **A**, Satellite image of the Taylor Region. **B**, Channel-margin ledge of the *Diplocraterion* bed in the Riverbend North Area (Loc. 304). **C**, The Taylor Section in the cutbank of the LowT/Riverbend Cliff Area (near Loc. 624). **D**, Satellite image of the McFall Ledge Tracksite and Section showing complex outcrop pattern from dipping beds. See Figure 3 for unit abbreviations.

B) that extends along both riverbanks around the long trail/Moni sites, along the outside cutbank of the LowT/Riverbend Cliff, and along the east (right) bank around the Riverbend North Sites. The track-bearing layer is about 30 cm below the *Diplocraterion* bed here.

The Taylor Section was measured above this shelf (Fig. 10C), and confirms that the Taylor track layer is not the same as the main track layer; the stratigraphy above the *Diplocraterion* bed does not match the succession above the main track layer. The *Diplocraterion* bed seems easy to identify visually in the McFall Ledge Site. The problem with correlating the Taylor track layer and the *Diplocraterion* bed from the LowT/Riverbend Cliff Area to the track-bearing beds at the McFall Ledge Tracksite is that the McFall Ledge is a few meters higher in elevation. Hence, rather than being in the river bed in its upstream position, the *Diplocraterion* bed at the McFall Ledge Site is about 3.3 m above water level. This suggests a monocline-like structural swell is evident in the horizontal stacking pattern of beds that crop out in the stream bed in the immediate vicinity of the McFall Section (Fig. 10D). Thus it seems pretty certain that the lower track layer of the McFall Ledge Site is indeed the same as the Taylor track layer, and that the upper track-bearing surface of the McFall Ledge is the top of the *Diplocraterio*n Bed. Thus the stratigraphic level of the Taylor track layer is established at just beneath the *Diplocratarion* bed, well above the steinkern marls (exposed at McFall). It is definitely not the same as the main track layer.

Map 2: The Highline Area

The Highline Area (Fig. 11A) is a stretch of riverbed that is mostly covered by alluvium. In contrast to the Taylor Area, the Highline Site tracks are certainly from the main track layer. The principal line of evidence is the full succession of stratigraphic markers proceeding in order from the Bluff Dale Sand just below the track bed, where it is breached in the Highline cutbank pool (Fig. 11B), the rubbly cobble-rich hardground bed, the fossiliferous steinkern marls and *Corbula* bed, the burrowed serpulid bed, to the *Diplocraterion* bed at the top of the Highline Section. At Highline the *Diplocraterion* bed is 4.4 m above water level. In the short distance downstream from the Rivercliff Bend North Sites, this elevation is a result of structural swelling. The alluvial cover in the area obscures most bedrock structure, but in a narrow channel that cuts against the west (left) bank just south of the Highline Tracksite, south-dipping beds are exposed as little cuesta-accentuated waterfalls. Visibly dipping beds can also be seen in the bank around this channel cut (Fig. 11C).

The B.S. 6 Site (Hawthorne, 1990) is also in the main track layer, as evidenced by the rubbly cobble-rich hardground bed and lower steinkern marl directly above it (Fig. 11D). Bedrock exposures were not observed in the area between the B.S. 6 Site and the Blue Hole Ballroom observed during our fieldwork, nor are any apparent in satellite imagery. In previous years, small exposures of the main track layer have been seen in this stretch of river. Assuming no dramatic geologic structures, the surface in this area should be very near the main track layer, and the bedrock subcrop beneath

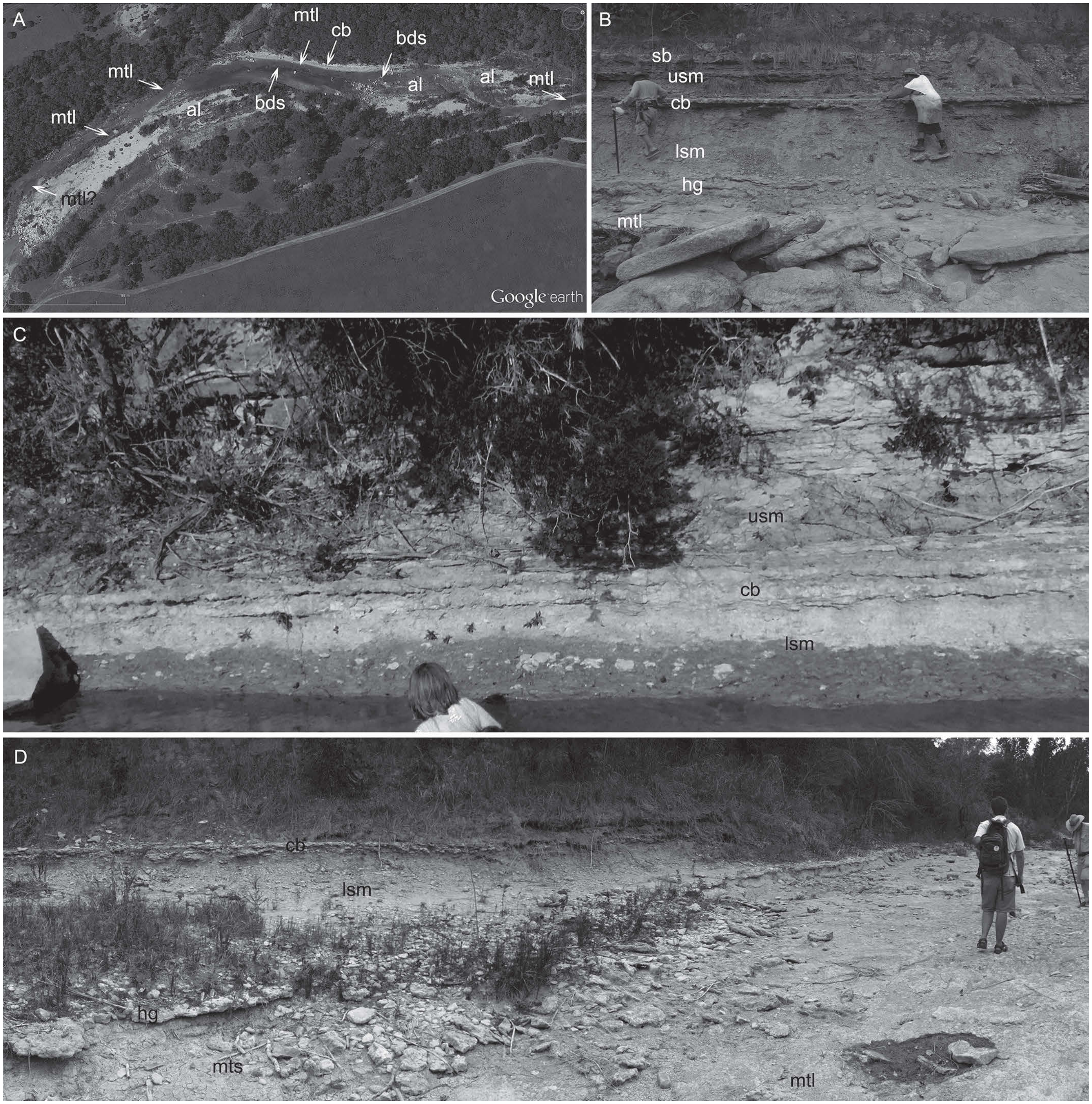

FIGURE 11. Photographs of Highline Area outcrops. **A**, Satellite image of the Highline Area. **B**, Highline Section (Loc. 303). **C**, Dipping steinkern marls and *Corbula* bed upstream of Highline Tracksites (Loc. 757). **D**, Stratigraphic section at B.S.-6 Tracksite showing succession from the main track layer through the *Corbula* bed. See Figure 3 for unit abbreviations.

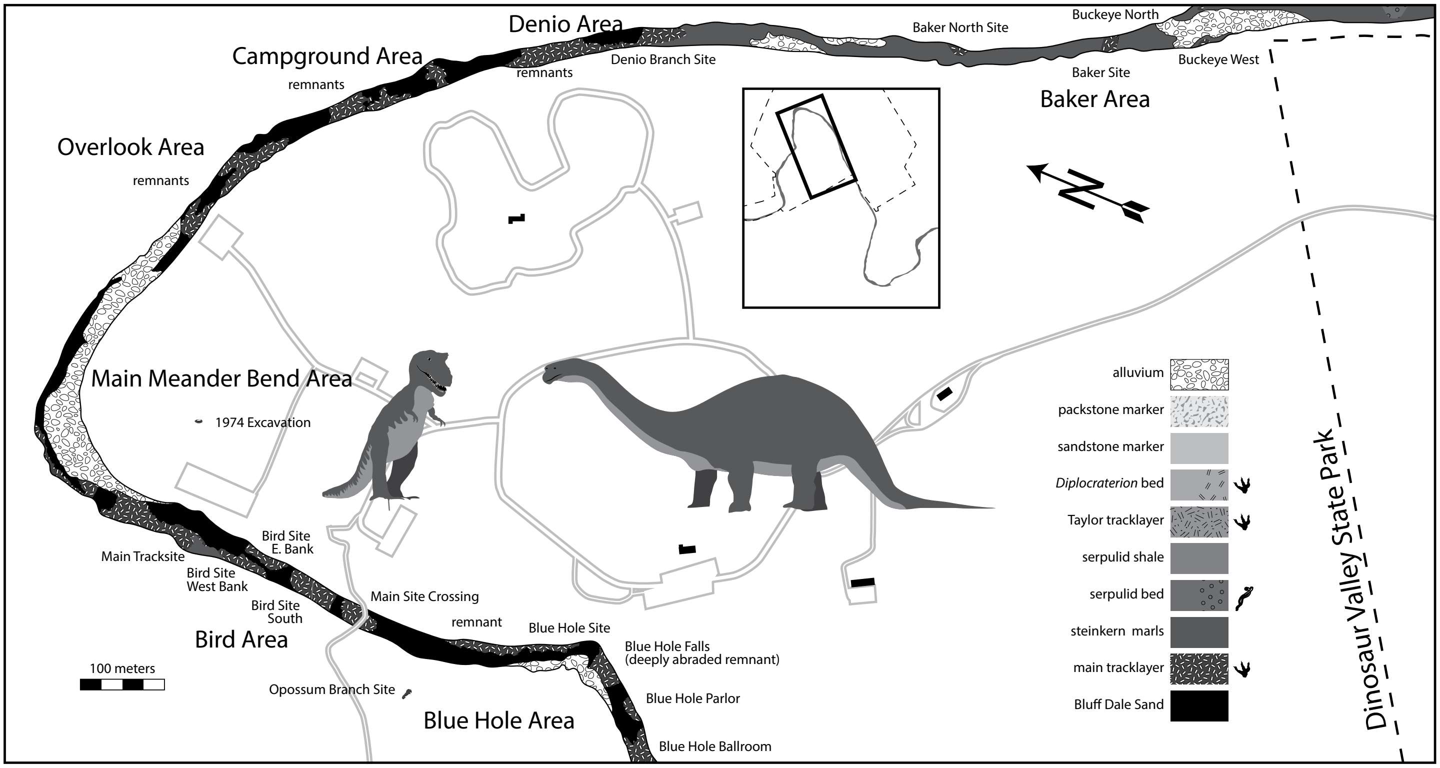

FIGURE 12. Preliminary geologic map of the Park Center Region. Note how in most of this region the tracksites are in the process of eroding away. The Denio Branch Tracksite is being eroded at the upstream end, and uncovered at the downstream end, and the Baker Area Sites are in the process of being uncovered.

the alluvium at any given point could be the Bluff Dale Sand, the main track layer, the hardground bed or the lower steinkern marl.

Map 3: Park Center Region

Consistent bed characteristics, elevation and stratigraphic context links tracks in the Park Center Region (Fig. 12), including the Blue Hole, Bird, Meander Bend, Overlook, Campground, and Denio areas, to the main track layer as defined at the Bird Area. The main track layer is well exposed in the Blue Hole Area. Here it is recognized chiefly as: 1) being a homogeneous bed without partings, 2) that fractures vertically into fully bed-thickness blocks, 3) that is covered in small burrow holes, and 4) that has exquisitely preserved dinosaur tracks. Preservation of the main track layer is spotty throughout the Park Center Region. The Blue Hole Area, the Blue Hole Ballroom and Blue Hole Parlor sites, freshly cleared of alluvium during the 2009 Field Season (Farlow et al., 2012), displayed pristine preservation of tracks. The Blue Hole Falls (Fig13A) shows mostly a full thickness of the main track layer, but tracks have been rendered into unrecognizable elongate rills by stream erosion (Fig. 13B). Similarly, the ledge of the Blue Hole Tracksite continues northward in a deeply-eroded condition. Breaching of the main track layer in the Blue Hole Region has led to exposure of a concretionary zone in the upper Bluff Dale Sand just beneath the main track layer, for example at the edge of the Blue Hole Parlor (Fig. 13C). The breach is quite obvious in the Blue Hole Cutbank Pool (Fig. 13A, D). A few meters of Bluff Dale Sand exposure lies generally beneath the water line (Fig. 13E) in this area. A significant point bar deposit (Fig. 13A) extends well back into the Blue Hole Parlor area (background in Fig. 13C). Thick alluvium covers much of the Blue Hole Cutbank Pool (Fig. 13F). Stratigraphic context above the Blue Hole Tracksite is provided by the Blue Hole Section measured in the cutbank exposure that goes through the Thorp Springs Member. Much of the study interval is poorly exposed, but the serpulid bed is clearly recognized by its abundant *Thalassinoides*. The *Diplocraterion* bed is also present as the most indurated ledge in the succession, but at this location no specimens of *Diplocraterion* traces were found.

The Bird Area (Farlow et al., 2012), the "type area" for the main track layer, exposes mostly the main track layer and, where breached, the underlying Bluff Dale Sand. The tracks are slightly eroded but recognizable (Fig. 14A-B). The photographs and section of track removed by Bird in 1940 compared with the current conditions of the Bird and Main Tracksites (e.g., Fig. 14C-E), affords an opportunity to study the rate of track destruction by fluvial processes, and preliminary investigation suggests a quantifiable loss (see Farlow et al., 2012). The Main Tracksite Section was measured in the excavated bank of the Main Tracksite, adjacent to the Bird Tracksite West Bank (Fig. 14D). Here the steinkern marls and *Corbula* bed are typically developed, but the hardground bed, rather than being a zone of encrusted and bored cobbles, is a continuous 10-30 cm ledge of hard packstone (Fig. 14C-E).

The main track layer was mostly removed from the sites of the Main Meander Bend Area, which leaves most of the main track layer in this area a channel-margin shelf along the cutbank (north, left bank), opposite a thick accumulation of alluvium in the point bar (Fig. 14F- G). More tracksites may lie buried beneath this thick alluvium. The cutbank includes a high-cliff exposure of the Glen Rose Formation that continues above the Thorp Springs Member, but obscures the lower part of the section.

The main track layer is largely eroded or removed in the Overlook Area as well (Fig. 15A). The cliff on the inside of the bend just beneath the park observation (Tracksite #1) area on the south (downstream right) bank (Fig. 15B) exposes strata at the upper

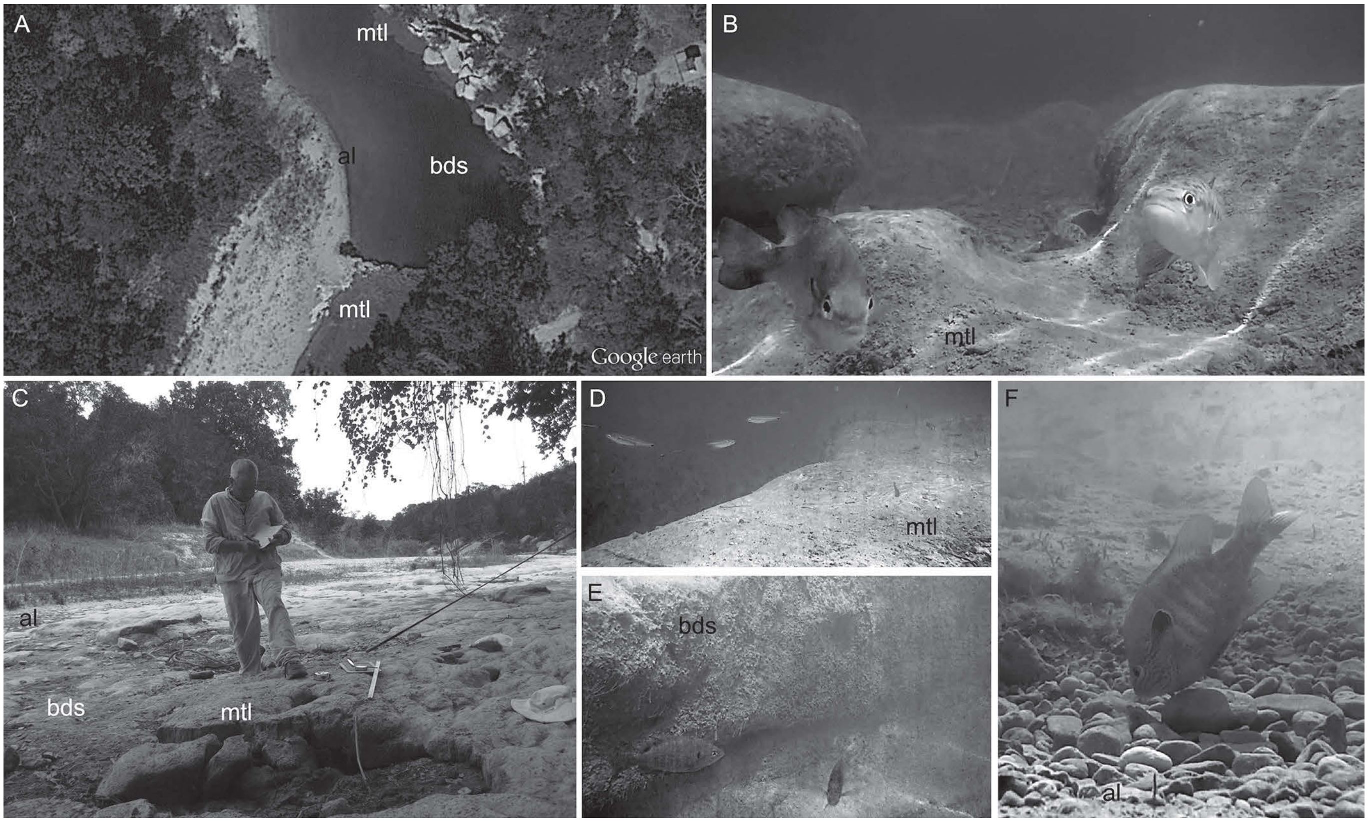

FIGURE 13. Photographs of the Blue Hole Area. **A**, Satellite image of the Blue Hole showing the cutbank pool, Blue Hole Falls ledge of main track layer, and thick alluvium of the point bar. **B**, Curious sunfish and bass swim among the eroded remnants of main track layer dinosaur tracks at the Blue Hole Falls. **C**, The edge of the Blue Hole Parlor Tracksite showing undermining and collapse of the main track layer over the roughly-textured Bluff Dale Sand, with point-bar alluvium in the background (Loc. 262). **D**, Minnows swim over the main track layer on the ledge of the Blue Hole Tracksite. **E**, the Bluff Dale Sand two meters below the overhanging main track layer ledge of the Blue Hole Site. **F**, A sunfish tends its nest in the submerged Blue Hole point-bar alluvium. See figure 3 for unit abbreviations.

surface of the main track layer through the serpulid bed, and shows another instance of the very thickly developed hardground bed. The outcrop extends for several meters, along which the hardground bed seems to become thinner. The bumpy surface of the Bluff Dale Sand concretionary "underbed" of the main track layer forms the stream bed in much of this area, where the true main track layer was recently removed by erosion (Fig. 15C). This surface has a bumpy appearance that can be confused with the main track layer. The Campground Area (Fig. 15D), once pretty rich in tracks, now contains mostly erosional remnants of the main track layer, and is floored by the concretionary layer of the upper Bluff Dale Sand (Fig. 15E).

The Denio Branch Tracksite (Fig. 16A) is interesting in that the upstream north end (Fig. 16B) is undergoing erosional destruction while the southern downstream end is being further exposed by erosion (Fig. 16C-D). For example, Denio Island (Fig. 16B) was actively reduced through all three field seasons by undermining around the edge (Fig. 16E), until a flood later in 2012, before the October 17 satellite imagery was taken (Fig. 16A), removed it entirely. Much of the area upstream of the leading edge of the Denio Tracksite is floored by the deeply-rilled surface of the upper Bluff Dale Sand concretionary horizon (Fig. 16B, F). The stratigraphic section (SV-1 of Nagle, 1967; Fig. 16A, D) above the main track layer at the Denio Site clearly exposes strata through the Serpulid Bed. Here the hardground bed is not a hard solid limestone but a thick zone of resistant rubbly-bedded marl with cobbles. The *Corbula* bed is typically developed, and the serpulid bed contained large serpulid mounds, but these were apparently eroded away prior to our fieldwork. From the ground (Fig. 16D) the Denio Tracksite suface is obviously dipping to the south or a few degrees SSW. The dip is apparent on satellite imagery (Fig. 16A) as a sweeping pattern of roughly east-west striking beds that appear to peel back from the western (right) bank.

The Baker Area (Fig. 17A) covers from this point southward to the Buckeye Branch Section, where the lower steinkern marl covers most of the river bed, with only a few emergences of the main track layer. These emergent tracksites include Baker North Site (Fig. 17B), the Baker Site proper (Fig. 17C), the Buckeye Branch North Site (Fig. 17D), and the Buckeye Branch West Site (Fig 17E). Between the Baker north and Baker sites is a triangular remnant of indurated bed (Fig. 17F) visible in satellite imagery (Fig. 17A). This is not a track exposure, but apparently is a synclinal remnant of the *Corbula* bed between the two anticlinally-exposed tracksites. The Buckeye Branch Section exposes strata through the *Diplocraterion* bed, and higher strata can be seen several tens of meters to the south. Here the hardground bed is more rubbly, the *Corbula* bed is the same, and the *Diplocraterion* bed contains more *Diplocraterion* traces than at any other location.

The thickness of strata between the main track layer and the *Corbula* bed at the Buckeye Branch Section is close to one meter, so through much of the area between the Denio Branch Tracksite and the Buckeye Branch Section, the main track layer lies less than one meter below the current bed of the Paluxy River. This area should be monitored carefully for new track exposures as erosion continues.

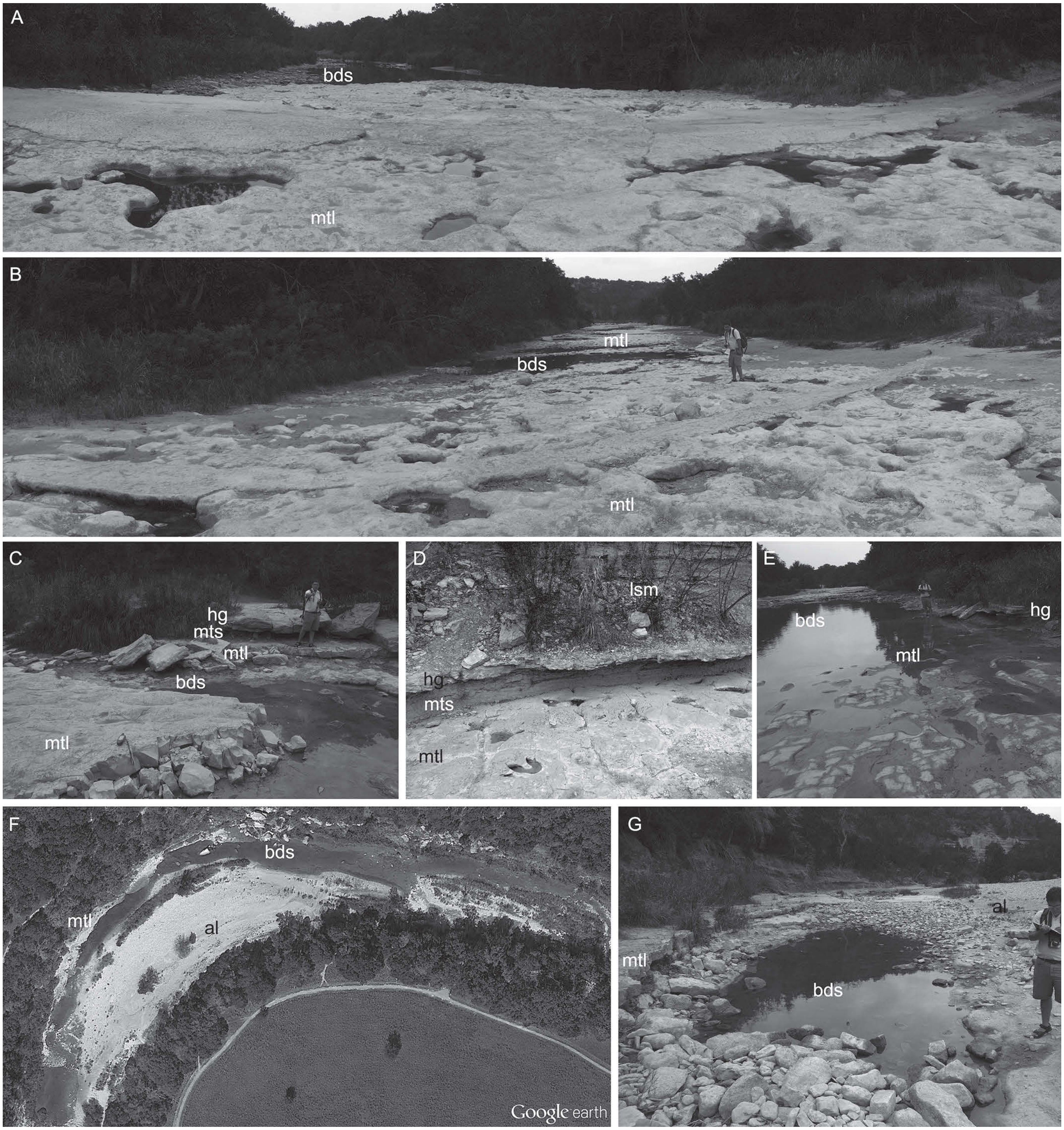

FIGURE 14. Photographs of the Bird Area and Main Meander Bend Area outcrops. **A, B,** Main Site Crossing (Loc. 264), looking south toward the Blue Hole (upstream, A), and looking north to the Bird Site South (downstream, B). **C-E**, Bird Site West Bank and Main Tracksite, showing north end of Bird Excavation (C, to viewer's left, Loc. 273) and south end of Main Tracksite (C, man standing), freshly uncovered tracks at the Main Tracksite (D), and southern end of Bird Site West Bank (E Loc. 270). **F**, Satellite image of the Main Meander Bend Area. **G**, looking downstream at the cutbank ledge remnant of the main track layer on the left with point bar alluvium in the background on the right (Loc. 273). See Figure 3 for unit abbreviations.

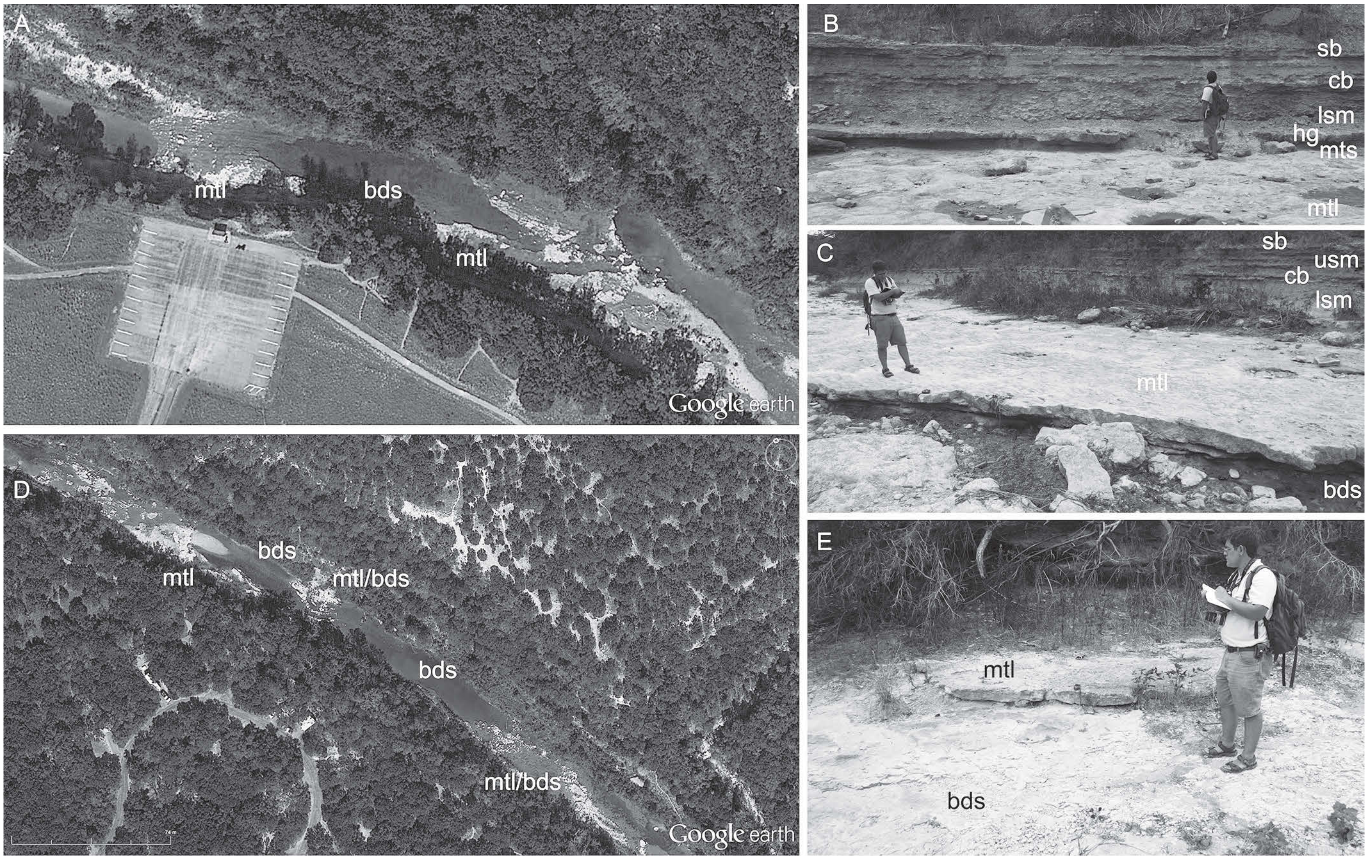

FIGURE 15. Photographs of the Overlook Area and Campground Area outcrops. **A**, Satellite image of the Overlook Area. **B**, The Overlook Section (Loc. 276). **C**, Remnant of the main track layer exposed at base of Overlook Section (Loc. 277). **D**, Satellite image of part of the Campground Area. **E**, Small remnant of the main track layer in the Campground Area (Loc. 281). See Figure 3 for unit abbreviations.

Map 4: Serpulid Mound Region

The Serpulid Mound Region is the riverbed between the mouth of Buckeye Branch and the FM 205 bridge near the current location of the Creation Evidence Museum (Fig. 18). The riverbed in this region is dominated by the serpulid bed, which forms a resistant ledge breached regularly by pools that expose the upper steinkern marl and possibly the lower steinkern marl. The transition into this zone is easily seen and marked by southward-dipping beds just south of Buckeye Branch, as evidenced by successively younger bed contacts sweeping from the Buckeye Section on the east (left) bank downstream (Fig. 19A-C). The first riverbed outcrop of the serpulid bed shows the characteristic stream-parallel rilling that develops in it, giving it an “alligator skin” texture recognizable in satellite images. This stretch of river marks the location of the first large serpulid mound that we encountered in the field. The quasi-periodic distribution of this unit through the mapped section of riverbed is exemplified in the area of Nagle’s (1967) SV-11 stratigraphic section (Fig. 19D-E). The alligator-skin texture is also apparent (Fig. 19D).

In just one stretch, about 250 meters in length, riverbed sediments are younger than the serpulid bed (Fig. 20A). Again, the southern downstreamward dipping and successive overlap of younger beds is apparent from outcrop pattern, both in the satellite image and from the ground (Fig. 20B). At the south end where the serpulid bed returns to the surface, the outcrop pattern is also apparent on satellite imagery (Fig. 20A, C). Further structural uplift occurs where the river course approaches the Creation Evidence Museum (Fig. 20D), in which a small outcrop of the lower steinkern marl peeks out from beneath alluvial gravels (Fig. 20E). The main track layer must subcrop beneath the alluvium somewhere behind the museum, because the Bluff Dale Sand is exposed just beyond the FM 205 bridge. During the fieldwork, this area was covered so deeply that the evidence was thoroughly obscured (Fig. 20F).

Map 5: Barker Branch Area

The first area of the Southeastern Meanderbend Region is the Barker Area. The Barker Branch Composite Section was measured from exposures in this area, and forms the key stratigraphic section in this paper (Fig. 3). The riverbed in the area (Fig. 21) is floored by a succession of units from the Bluff Dale Sand through the serpulid bed. Determination of stratigraphic position is simple here; a continuous clean stratigraphic exposure runs for hundreds of meters around the bend along the southern (right) cutbank of the river (Fig. 22A). The Bluff Dale Sand is first exposed where the thalweg alluvial deposit (continuous from behind the Creation Evidence Museum) ends in the deep cutbank pool north of Bowden Branch. Here the Bluff Dale Sand, main track layer, hardground bed and lower steinkern marl are exposed in the cutbank (Fig. 22B). The downstream southern end of the pool is marked by a ledge of the main track layer, the beginning of the Al West Tracksite, with a cutbank section that exposes units through the serpulid bed (Fig. 22C). The Al West Tracksite exposure of the main track layer continues around the point bar (on the north, left side) past the mouth of Bowden Branch (Fig. 22D-E). Here it shows minor structural swells and swales, and is just emergent from the overlying main

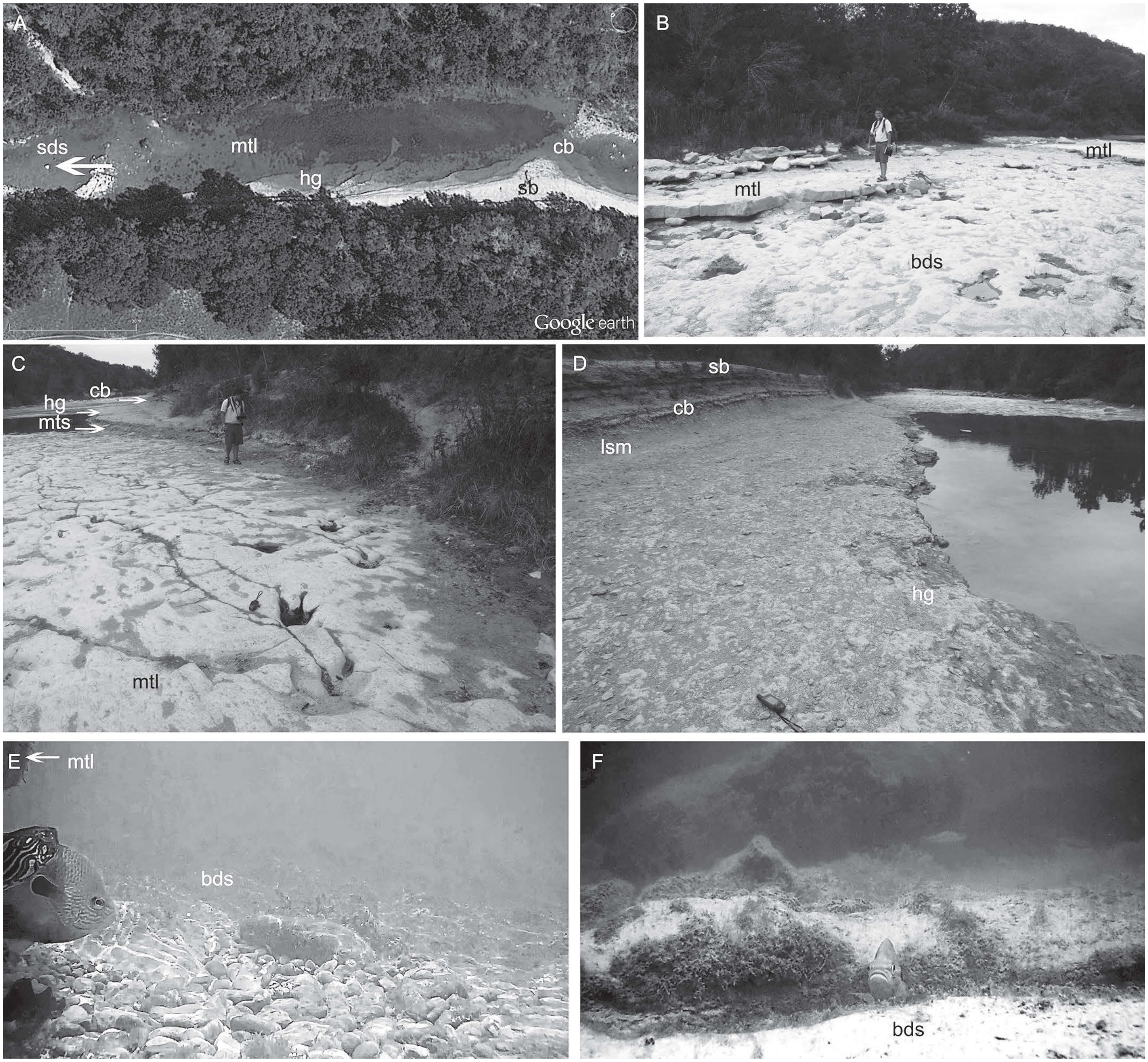

FIGURE 16. Photographs of outcrops at the Denio Branch Tracksite and Stratigraphic Section. **A**, Satellite image of the Denio Branch Tracksite and Section; arrow indicates small island remnant of main track layer destroyed after the summer of 2012. **B**, Island of the main track layer at Denio during summer of 2009 (Loc. 282). **C**, View from Denio Branch Tracksite looking downstream (south) toward Denio Stratigraphic Section (Loc. 283). **D**, View from Denio Stratigraphic Section looking upstream (north) to Denio Branch Tracksite (Loc. 285). **E**, Sunfish and turtle seek shelter under the overhanging ledge of the island of main track layer (also illustrated in B) during the summer of 2012, before the "island" was removed by a flood. **F**, Sunfish hides in a deep rill of the Bluff Dale Sand. See Figure 3 for unit abbreviations.

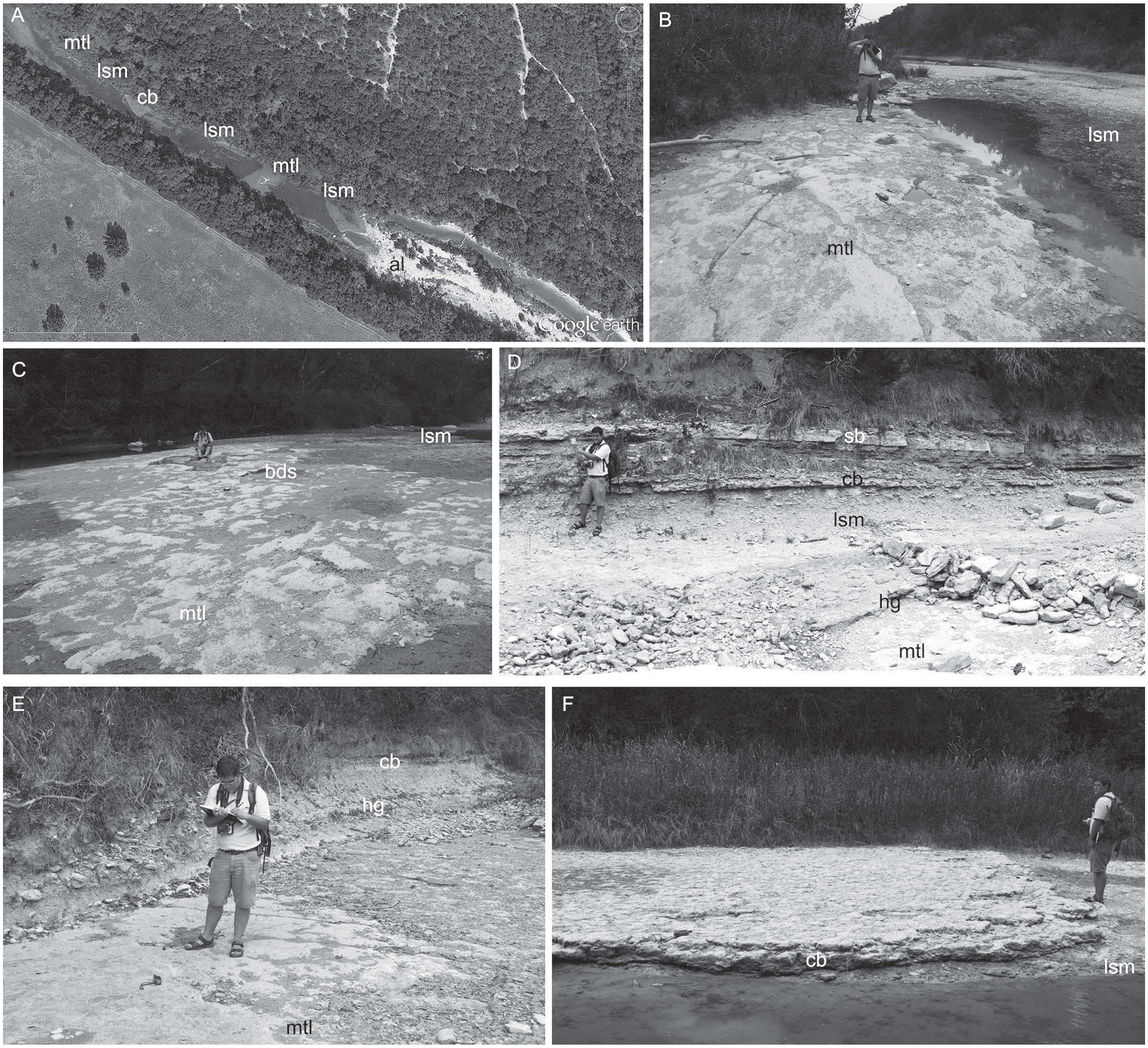

FIGURE 17. Photographs of Baker Area outcrops. **A**, Satellite image of the Baker Area. **B**, "Baker North" emergent outcrop of the main track layer (Loc. 287). **C**, The Baker Tracksite (Loc. 290). **D**, Buckeye North Tracksite (Loc. 292). **E**, Buckeye West Tracksite (Loc. 291). **F**, Exposure of *Corbula* bed between the Baker North and Baker Sites, indicating a minor synclinal axis (Loc. 289). See Figure 3 for unit abbreviations.

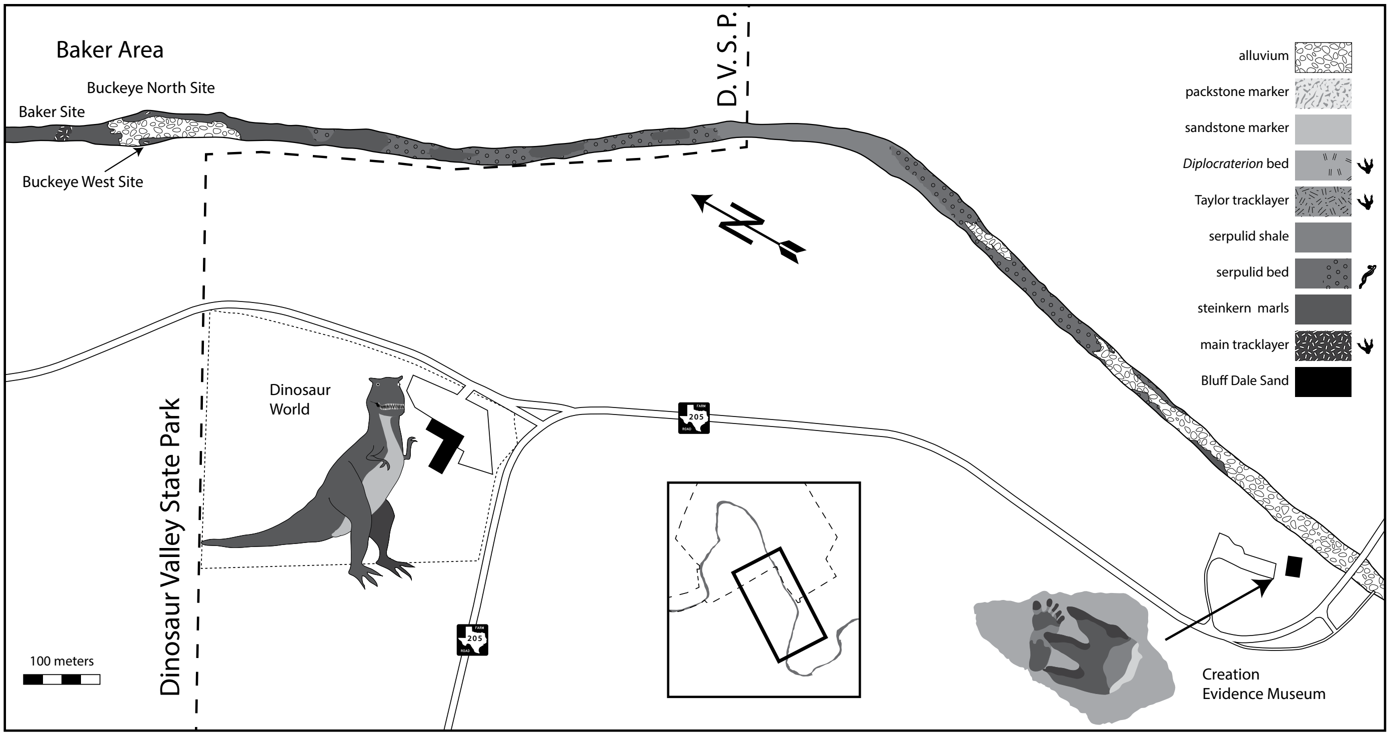

FIGURE 18. Preliminary geologic map of the Serpulid Mound Region showing mostly exposures of the serpulid bed.

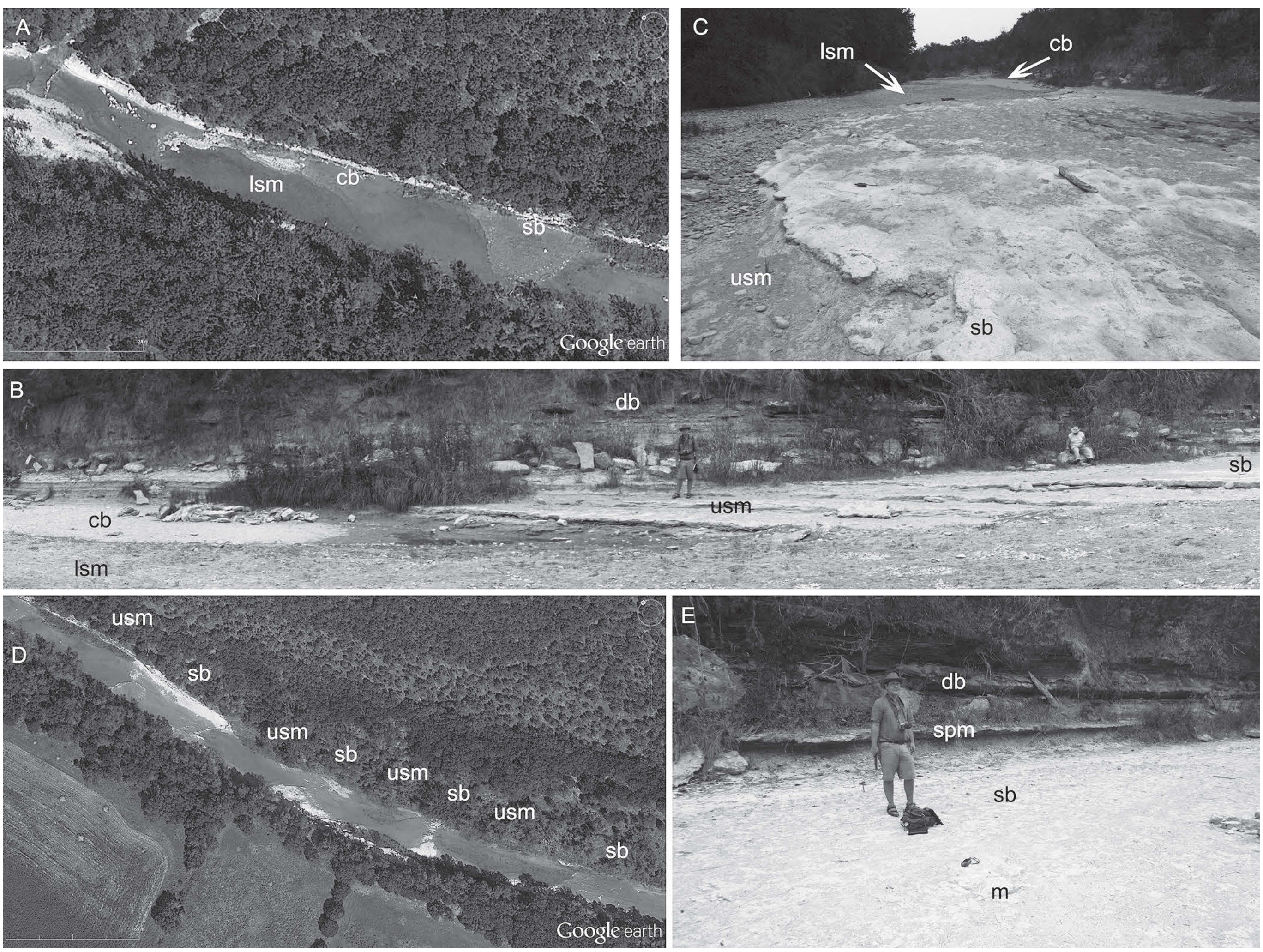

FIGURE 19. Photographs of the Northern (upstream) Serpulid Mound Region. **A**, Satellite image of the area of south-dipping beds downstream from Buckeye Branch, showing transition from the Baker Area into the Serpulid Mound Region. **B**, Panorama showing the stair-step outcrop pattern in the transitional area (Loc. 314). **C**, Northernmost streambed exposure of the serpulid bed in the Serpulid Mound Region (Loc. 296). **D**, Satellite image of the evenly-spaced outcrops of the serpulid bed in the Northern Serpulid Mound Region. **E**, Stratigraphic Section SV-11 on west (right of downstream) bank of the river (Nagle 1968; Loc. 316). See Figure 3 for unit abbreviations.

FIGURE 20. Photographs of outcrops in the southern (downstream) end of the Serpulid Mound Region. **A**, Satellite image of the serpulid shale-covered part of the riverbed (compare Fig. 19). **B**, Upstream (northern) edge of serpulid shale outcrop (Loc. 317). **C**, Downstream (southern) edge of serpulid shale outcrop (Loc 319). **D**, Satellite image of the Creation Evidence Museum and FM 205 Bridge ("Third Crossing" of local terminology) area. **E**, Steinkern marl exposure upstream of Creation Evidence Museum (to the right above riverbank), surrounded by alluvial cover (Loc. 323). **F**, View southward of alluvium covered riverbed from behind the Creation Evidence Museum to beyond the FM 205 Bridge (Loc. 324). See Figure 3 for unit abbreviations.

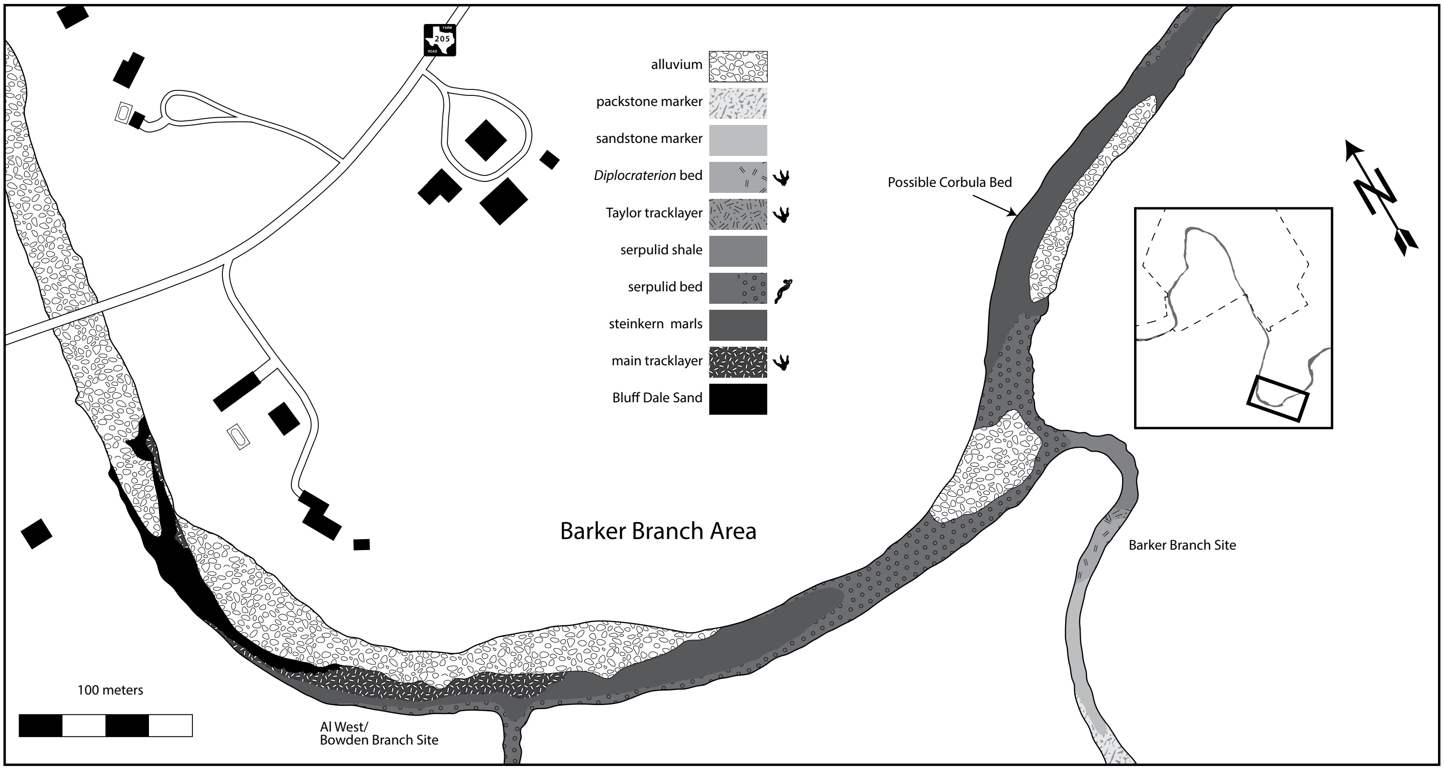

FIGURE 21. Preliminary geologic map of the Barker Branch Area of the SE Meander Bend Region showing continuous exposure of the entire stratigraphic section between the Bluff Dale Sand through the upper beds (sandstone marker and packstone marker).

track shale and hardground bed. The stratigraphic bank exposure continues as well, and wraps into the mouth of Bowden Branch (Fig. 23F) where the serpulid bed forms a small waterfall. The thin covering of lower steinkern marl and the covering of point bar alluvium over the main track layer in this area suggest a large area of potential future erosional unveiling of the Al West Tracksite. The serpulid bed covers the stream bed more than 100 m downstream of Bowden Branch. At Barker Branch the serpulid bed is exposed in the floor of the river (Figs. 21, 23A). Just downstream from this point the structure rises again, and the upper steinkern marl is exposed. A small bedding-plane outcrop 120 meters downstream from the mouth of Barker Branch is interpreted as an exposure of the *Corbula* bed.

The section at the mouth of Barker Branch (Fig. 23B) exposes continuously from the serpulid bed through the Thorp Springs Member. To examine bedding plane surfaces, and get a better idea of how these beds correlate upstream to the Taylor track layer and to the *Diplocraterion* bed, and downstream to the track layer exposed at the Jeannie Mack and CR 1001 Crossing Tracksites, several of them were traced around the bend into Barker Branch tributary stream. These beds stratigraphically constrained the Barker Branch Section (Fig. 3) and thus are the key to linking those tracksites to others in the park. From this work we conclude that the Taylor Track layer is at 5.4 m and that the *Diplocraterion* bed is at 5.5 m in the composite section (Fig. 3; Fig. 23C). For correlation to the Jeannie Mack and CR 1001 Sites, we also noted two additional unique marker beds (Fig. 23D), the first at 5.8 m, the marker sandstone, and a second at 6.1 m, the marker packstone. A single tridactyl track with associated mudcracks was seen in this putative Taylor track layer in Barker Branch (Fig. 23E). It is directly overlain by what we identify as the *Diplocraterion* bed. *Diplocraterion* traces are abundant at the section, and the upper bedding surface is very irregular or bumpy. It bears a few rare recognizable tracks at the Barker Branch Tracksite (Fig. 23F-G). We interpret this irregular surface as resulting from multiple overlapping dinosaur tracks, sometimes called "dinoturbation" (Lockley, 1991). The marker sandstone forms the next flat ledge surface flooring a shallow pool in Barker Branch (Fig. 23H), where it is dotted with scattered *Diplocraterion* (Fig. 23I). The marker packstone is a silty packstone with an unusually-textured botryoidal and intensely bioturbated surface (Fig. 23J), and lies a little more than 10 cm above the top of the marker sandstone.

The composite section was generated from four legs of section where different units were exposed: 1) the Bluff Dale Sand and main track layer at the Cut Bank Pool (Fig. 22B), 2) the lower steinkern marl and *Corbula* bed at the Al West Site on the southeastern edge of the pool (Fig. 22C), 3) the upper steinkern marl and serpulid bed from the exposure just south of the mouth of Bowden Branch (Fig. 22E), and the rest of the section through the packstone marker bed (and above) at the cliff exposure at the mouth of Barker Branch (Fig. 23B).

Map 6: Jeannie Mack Area

The Jeannie Mack and CO 1001 crossing tracksites (Figs. 24-26) are the sites that have proven most difficult to correlate in the past. This is partly a function of their long-distance separation from other tracksites through the intervening Serpulid Mound Region of the river. Hawthorne (1990) suggested that the tracks at the Jeannie Mack (his "Lancaster Ranch") Site were formed in the serpulid bed. By carefully matching marker beds from the Barker Branch Tracksite and Section, where the position of the serpulid bed is well constrained, we hypothesize that the Jeannie Mack and CR 1001 Crossing Area tracksites formed in the Taylor track layer.

Structurally the putative outcrop of the *Corbula* bed just downstream of the mouth of Barker Branch appears to be the anticlinal

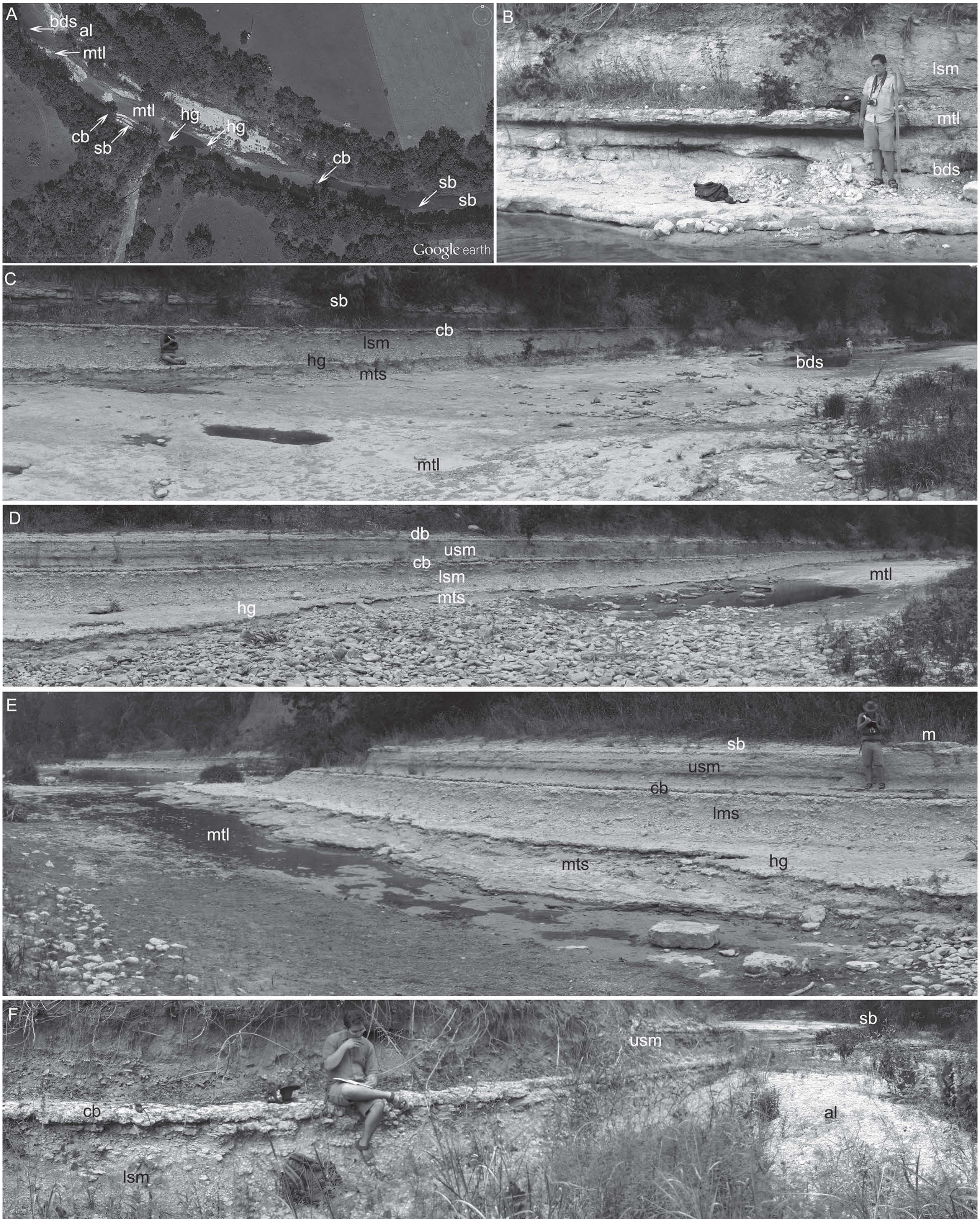

FIGURE 22. Photographs of outcrops near Bowden Branch. **A**, Satellite image of the mouth of Bowden Branch. **B**, Bluff Dale Sand outcrop above the western (downstream right) cutbank pool (Loc. 347). **C**, Al West Site with main track layer in the riverbed and overlying stratigraphic section through the serpulid bed (Loc. 325). **D, E**, Split panoramic image taken from midway between the Al West Tracksite and the Mouth of Bowden Branch (Loc 326), with half looking upstream toward the Al West Tracksite (D), and the other half looking downstream toward the mouth of Bowden Branch (E). **F**, Panorama taken from near the eastern bank of Bowden Branch at the mouth of the tributary (Loc. 327), showing an exposure of the *Corbula* bed that forms a convenient bench seat, and the serpulid bed forming a water fall farther upstream in the channel. See Figure 3 for unit abbreviations.

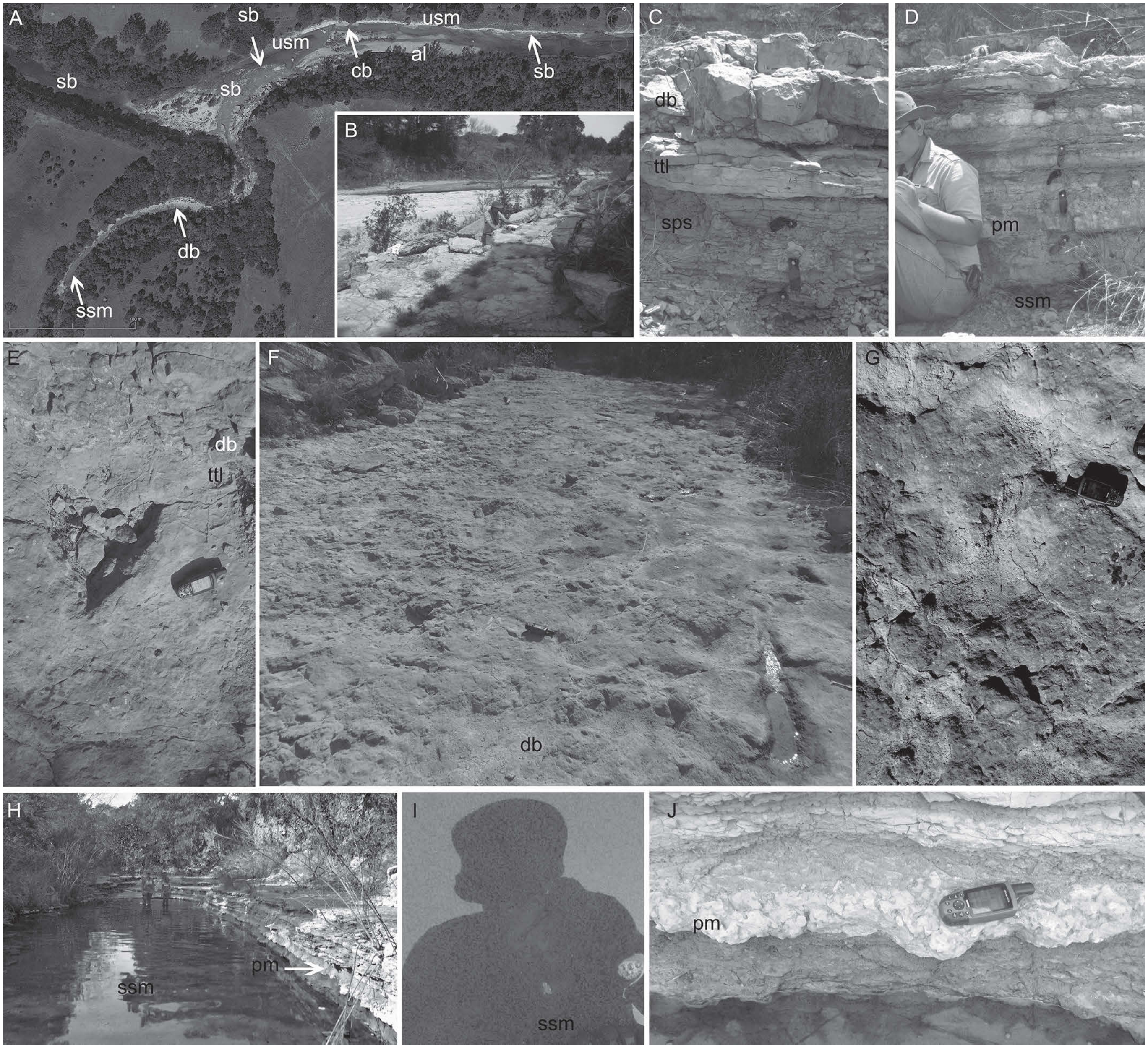

FIGURE 23. Photographs of outcrops in and around Barker Branch. **A**, Satellite image of the area around the Mouth of Barker Branch. **B-D**, Barker Branch Stratigraphic Section (B, Loc 329), with closeup of Taylor track layer and *Diplocraterion* bed (C), and of the sandstone marker and packstone marker beds (D). **E**, Taylor track layer mudcracks and probable track in the Barker Branch Tributary (Loc. 760). **F,G**, Surface of the *Diplocraterion* bed in the Barker Branch Tributary (Loc. 761), showing the highly bioturbated, bumpy surface (F), and a faintly-recognizable possible individual tridactyl footprint (G). **H-J**, Pool farther up the Barker Branch Tributary (H, Loc. 763), floored by sandstone marker with sparse *Diplocraterion* (I), and with the packstone marker exposed in the wall (H, J). See Figure 3 for unit abbreviations.

peak in the area. The next outcrop of the serpulid bed (Fig. 25B) is 130 meters downstream from this point, or 180 meters upstream from the upstream edge of the Jeannie Mack Site (Fig. 25C). A series of beds can be seen dipping NNW (left of downstream) toward the Jeannie Mack Tracksite. The track-bearing horizon at the Jeannie Mack Site dips slightly upstream (Fig 25D). The bed in close contact just above the track-bearing horizon is visible on the NW (left) bank of the tracksite, and is characterized by a bumpy surface that can be seen in satellite (Fig. 25C) as well as in outcrop (Figs. 25E-F). This horizon bears a remarkable similarity to the *Diplocraterion* bed as recognized in Barker Branch. We argue that the Jeannie Mack Tracksite surface(s) is the Taylor track layer, and that the bumpy bed is the *Diplocraterion* bed.

Looking downstream from the Jeannie Mack Site (Figs. 25G-H), the continued NNE dip is apparent. The overlapping relationship of beds is unmistakable from satellite imagery (Fig. 25A, C); two distinct ledges overlap, the first fully, and the second restricted to the outside of the last bend before the CR 1001 Crossing Tracksite. Field examination of this last bed revealed the unusual texture of the packstone marker bed, which constrains the lower bed as the sandstone marker bed.

The CR 1001 Crossing Site (Fig. 26A) is a rapids exposure whose crest is the sandstone marker bed, and that cuts through the *Diplocraterion* bed, the Taylor Track layer and the beds below in succession (Fig. 26B-C).

DISCUSSION

One of the results of this high-resolution correlation effort has been to precisely identify the stratigraphic correlations between all

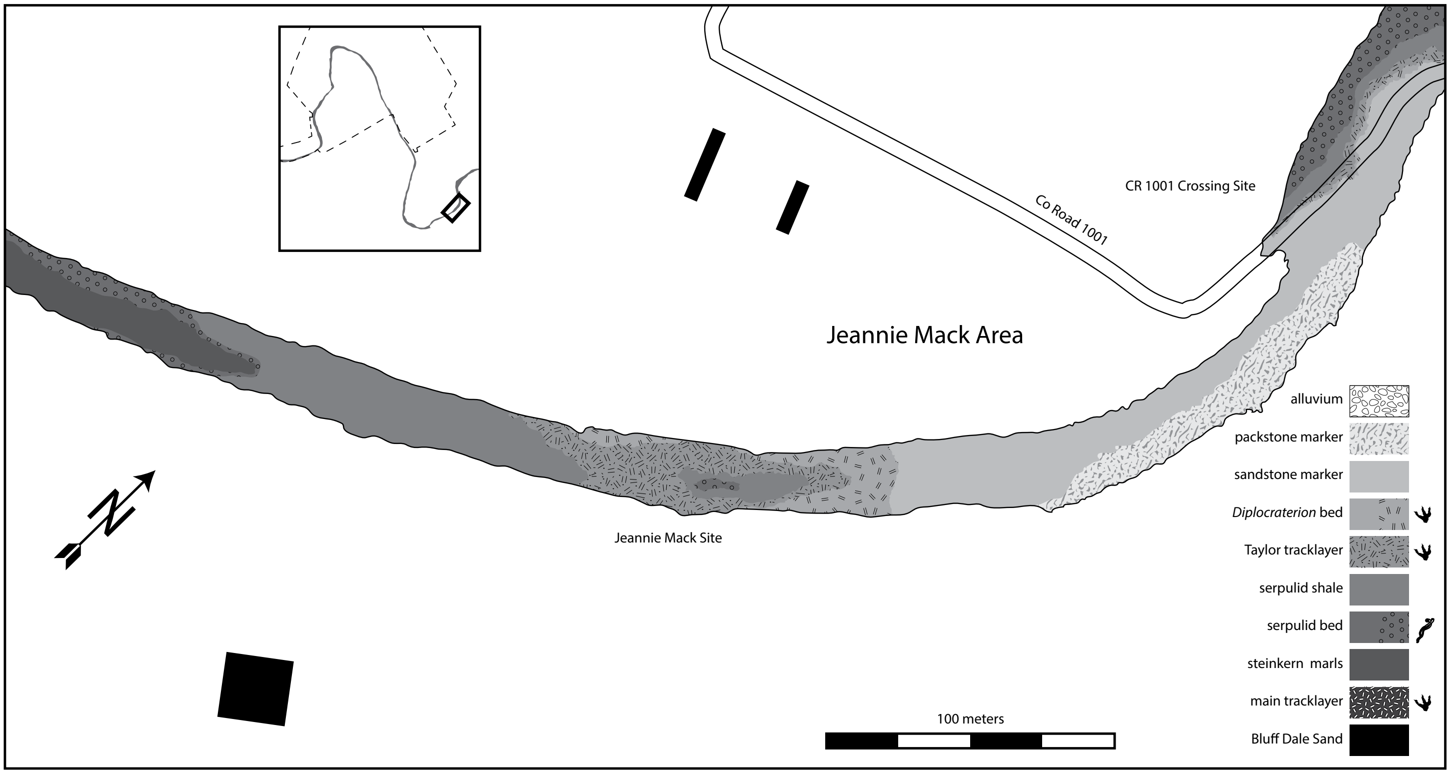

FIGURE 24. Preliminary geologic map of the Jeannie Mack Area showing correlations of the Jeannie Mack Tracksite, the County Road 1001 Crossing Tracksite, and their relationship to the serpulid bed and upper beds (sandstone marker and packstone marker) that are exposed in the Barker Branch Area just to the west.

of the known tracksites in the study area. These results are summarized in Figure 27, which is a generalized stratigraphic cross section along the course of the river. The high-resolution geologic maps are also summarized as a more generalized map (Fig. 28) showing outcrop intervals along the entire stretch of the Paluxy through the Dinosaur Valley State Park area.

The Three Track Layers and Structural Controls on Their Distribution

The cross section clearly shows that tracks are restricted to two thin stratigraphic zones. The lower one is a simple, single bed occurrence in the main track layer, and the upper one is a more complex occurrence that involves both the Taylor track layer and the *Diplocraterion* bed. Although tracksites in the Park Center Region pertain to the lower main track layer occurrence, tracksites on the periphery or outside of the park (DVSP boundaries shown in Fig. 1) are more likely to be in the upper two layers, the Taylor track layer, or more rarely in the *Diplocraterion* bed.

This pattern is mostly a function of the southeastern regional dip of the Glen Rose Formation: the Thorp Springs Member is well above ground level in the village of Paluxy (Nagle, 1968), which is up-river to the northwest from the park, while the Thorp Springs Member forms the bed of the Paluxy in Glen Rose. Naturally the Main Meander Bend in the Park Center Region exposes the older main track layer because it is farther north than either the Taylor Area or the Southeastern Meander Bend Region.

However, the strata of the Paluxy River, while nearly flat, are not perfectly flat. Local swells and swales account for up to 7 m of structural relief, therefore causing some complexity in the outcrop pattern. For example, the lack of significant exposure of the serpulid bed between the Taylor Area and the Highline Tracksite is a fuction of a local structural swell or monocline-like rise as one passes downstream from the Taylor Area. Similarly, the localized exposure of the main track layer at the Al West Tracksite suggests a minor uplift. Undulatory swells and swales at the geographic scale of tens of meters, may account for as much as a meter of local structural relief. This explains the almost periodic patterns seen throughout the study area, separating remnant tracksites like pearls on a string between the Blue Hole and the Main Meander Bend, or between the Main Meander Bend and the Denio Tracksite (Fig. 12), or separating exposures of the serpulid bed at regular intervals in the Serpulid Mound Region (Figs. 18, 19D).

Erosion and the Conservation of Tracksite Resources

Since the earliest studies of tracksites in the Paluxy River the ephemeral nature of track layer exposures has been noted (Shuler, 1937); the erosional processes that expose the track layers will eventually, and sometimes suddenly, in one torrential flood, destroy them. Preventing this may be futile, but understanding the stratigraphy affords the ability to discern which tracksites are in the process of destruction and where new tracksites are likely to emerge.

For example, the complete destruction of the “Denio Island” (Fig. 16A,B,E) late in 2012 was reasonably foreseeable, even from these figures, and was not surprising to the authors. The removal of paleontological resources from their original contexts (e.g., Bird, 1941) has had negative paleontological and cultural consequences (e.g., Mayor, 2005), so the effort to conserve these resources in their native settings is laudable. However, we would argue that in a situation like this, when the eminent destruction of a section of tracksite is recognized, collection and curation for educational display or scientific study may be justified.

FIGURE 25. Outcrop photos of the Jeannie Mack Tracksite. **A**, Satellite image showing both the Jeannie Mack Tracksite and County Road 1001 Crossing Tracksite. **B**, Satellite image of the southwest edge of the Jeannie Mack Tracksite showing overlapping beds building from the serpulid bed in the southwest corner to the Taylor track layer in the northeast corner. **C**, Satellite image of the Jeannie Mack Tracksite. **D**, Photograph taken from a ladder over the Jeannie Mack Tracksite looking upstream (southwest) toward the serpulid bed outcrops. **E**, Photograph taken from the ladder over the northwest bank of the tracksite and looking south-southeast toward the south bank showing the *Diplocraterion* bed overlapping the Taylor track layer. **F**, Detail of the bumpy surface of the *Diplocraterion* bed (Loc. 759, compare Fig. 23F). **G, H**, Photographs from ladder, looking downstream (eastward) from the tracksite, showing a slight swell of the Taylor track layer at the edge of a deep pool (G), and then an eastward dip which submerges the Taylor track layer and the overlapping *Diplocraterion* bed (H). See Figure 3 for unit abbreviations.

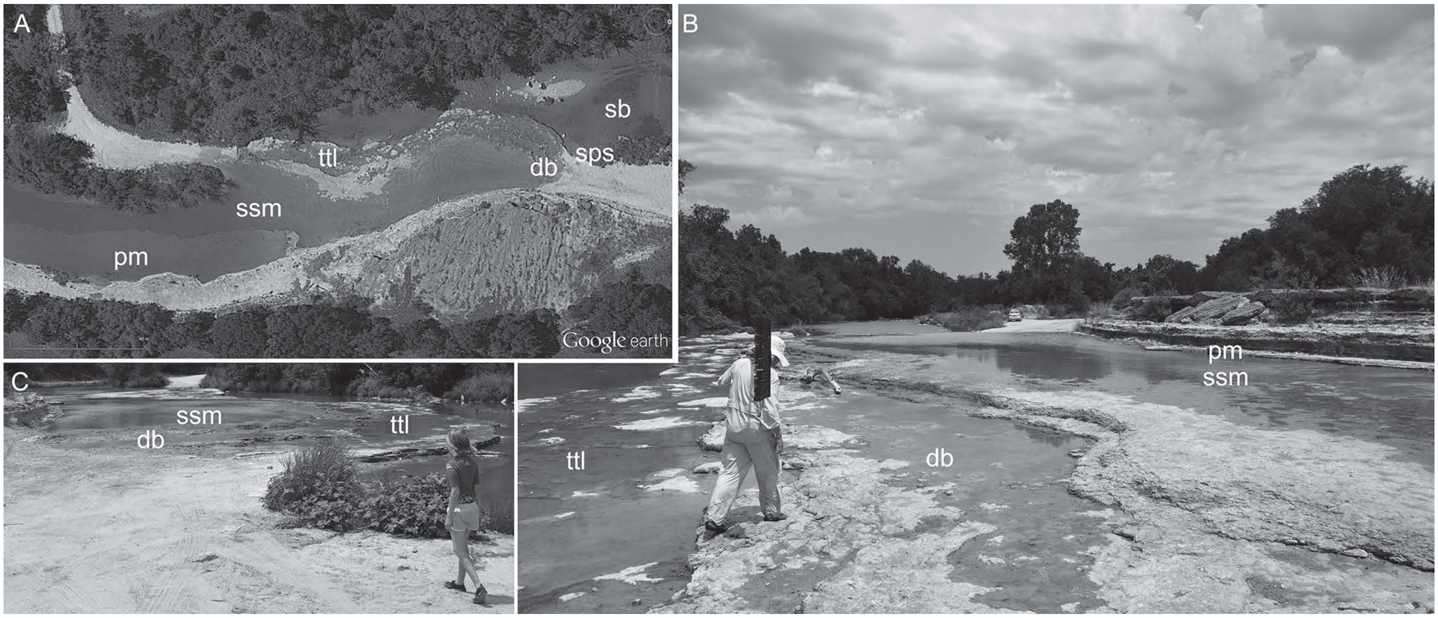

FIGURE 26. County Road 1001 Tracksite. **A**, Satellite Image of the tracksite showing overlapping relationships. **B**, Outcrop view looking along the road northward from the western (downstream left) bank. **C**, Outcrop view looking along the road southward from the eastern (downstream right) bank. See Figure 3 for unit abbreviations.

On the other side of the spectrum, some areas of the park are ripe for new exposures, and occasional reconnaissance of these areas is warranted to take full advantage of limited opportunities for study. Ephemeral exposures include places where shifting of alluvial cover might only temporarily reveal track bed surfaces, as in the Highline Area, the area between the Highline area and the Blue Hole Ballroom, or the point bar in the Main Meander Bend Area. More permanent exposures might be created by erosional removal of the lower steinkern marl from the downstream end of the Denio Tracksite, or from the riverbed in the Baker Area, as well as upstream from the Highline Tracksites.

Beds, Facies and the Importance of Events

From the standpoint of the stratigrapher, sedimentologist, or paleontologist trying to understand past environments, unravel sedimentary processes, or glean some information about dinosaur ecology, this study lays the foundation for investigation of numerous questions.

The overall pattern is that water deepened after the deposition of the main track layer, then shallowed before deposition of the Taylor track layer and began deepening again before the deposition of the *Diplocraterion* bed. The previous studies in this area have viewed rocks as records of paleoenvironment, so some of these questions have been addressed (Behrens, 1965; Nagle, 1968). Dinosaur tracks are an excellent indicator that water was no more than "dinosaur deep." So, the rocks certainly record environment, but to look at environment alone is to miss something. For example, the distinctiveness of the main track layer to main track shale couplet suggests that track preservation is not simply a function of depositional environment, but is related to depositional processes that may be the result of unique events. Similarly, the *Corbula* bed, a seemingly unrelated phenomenon—it is a strange accumulation of small clams—is at least as likely to owe this faunal composition to taphonomic processes as it is to represent a truly diminutive, nearly monotypic fauna whose depositional environment sedimentologists and stratigraphers have been puzzling over for some time now (Behrens, 1965; Nagle, 1968). Questions concerning regional correlation to better-known sections in Texas (e.g., Scott et al., 2007; Ward and Ward, 2007), depositional process, taphonomy and ichnology are the subject of ongoing study by some of the authors.

CONCLUSIONS

This study has resulted in the following conclusions:

There are three track-bearing horizons arranged in two clusters exposed in the bed of the Paluxy River in the area of Dinosaur Valley State Park: the lower main track layer characteristic of the familiar Park Center Region, and the Taylor track layer and *Diplocraterion* bed, which are exposed at the upstream and beyond the downstream ends of the park area.

Marine sediments separate the two track zones, suggesting a rise and fall in sea level.

The abundant tracksites in the Park Center Region are being eroded, including the upstream end of the Denio Tracksite. However, new tracks are being exposed by erosion in the downstream end of the Denio Tracksite and in the Baker Area, where more tracksites are likely to be exposed in the future.

ACKNOWLEDGMENTS

This research was supported by grants from the National Geographic Society, Indiana University and Indiana Purdue University Fort Wayne to Farlow, and by a grant from the U.S. National Natural Landmarks Program to O'Brien. Anthony J. Martin is grateful to the Department of Environmental Studies, Emory University, for travel support. Logistic support in the field was provided by the staff of Dinosaur Valley State Park and the Texas Department of Parks and Wildlife. Mr. Jerry Jacene, Chris Gotcher, Alex Dattilo and numerous other volunteers helped us considerably with fieldwork. Photographs for Figures 26B, C courtesy of Daniel Dattilo. Outside reviewer Robert W. Scott provided many helpful comments to improve the manuscript.

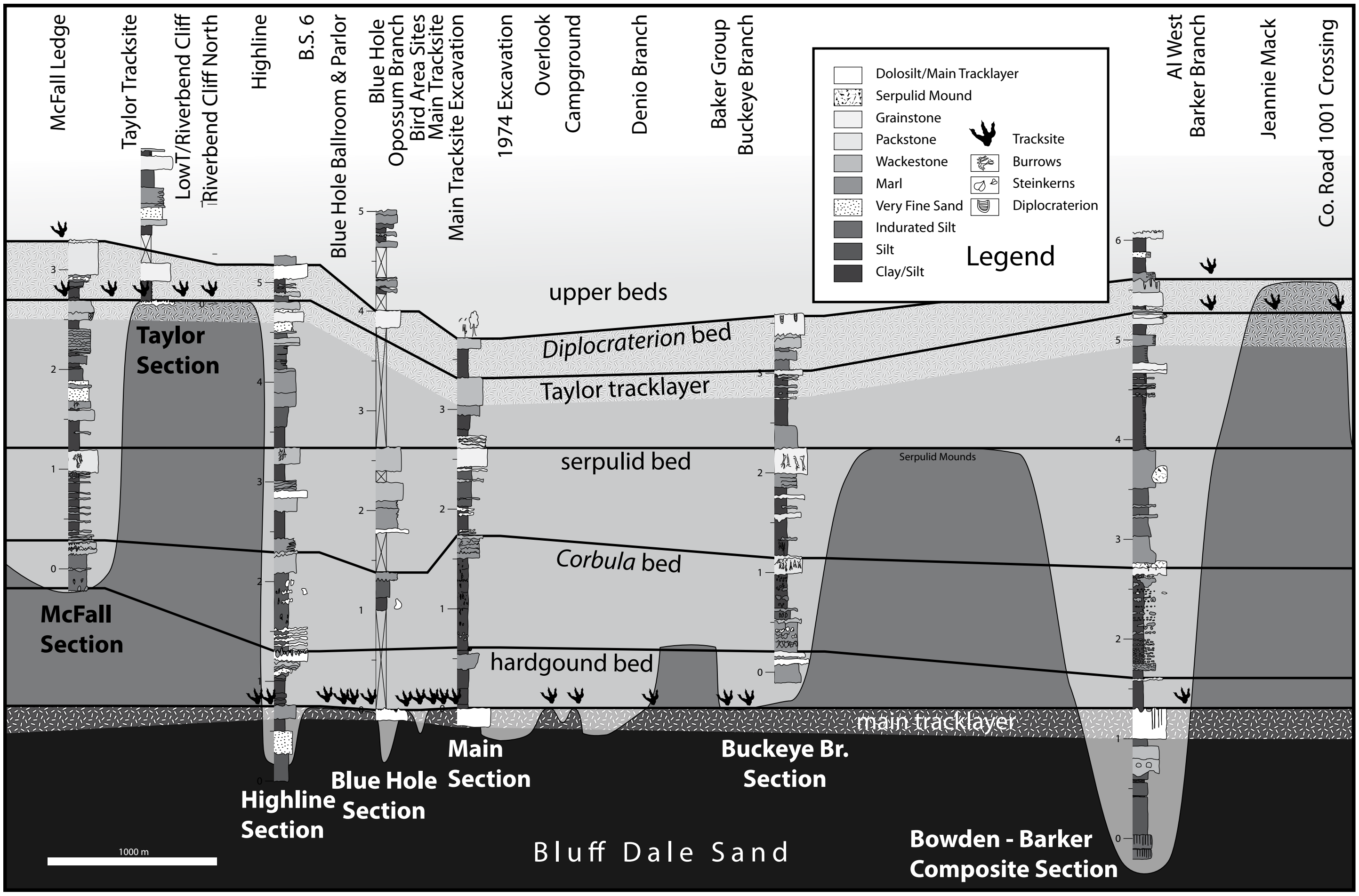

FIGURE 27. Stratigraphic cross section of Paluxy River track layers and intervening strata taken along the course of the river and hung on the upper surface of the main track layer. The riverbed is represented by the boundary between bright and dimmed color coding. In reality the main track layer is neither level nor flat, but dips regionally to the southeast, and undulates at scales of tens to hundreds of meters. Thus, the diagram does not reflect the elevation profile of the riverbed. See Figure 3 for key to colors.

REFERENCES

Behrens, E.W., 1965, Environment reconstruction for a part of the Glen Rose Limestone, central Texas: Sedimentology, v. 4, p. 65-111.

Bird, R.T., 1939, Thunder in his footsteps: Natural History, v. 43. p. 254-261.

Bird, R.T., 1941, A dinosaur walks into the museum: Natural History, v. 47, p. 74-81.

Bird, R.T., 1944, Did Brontosaurus ever walk on land?: Natural History, v. 53, p. 61-67.

Bird, R.T., 1954, We captured a “live” brontosaur: National Geographic, v. 105, p. 707-722.

Bird, R.T., 1985, Bones for Barnum Brown: Adventures of a Dinosaur Hunter (edited by Schreiber, V.T.). Texas Christian University Press, Fort Worth, TX, p. 1-225.

Curtis, A.B., 1988, Paleoecology and paleontology of serpulid bioherms in the lower Glen Rose Limestone of Central Texas. Unpublished B.S. Thesis, Baylor University, Waco, Texas.

Farlow, J.M. O’Brien, G.J., Kuban, B.F., Dattilo, K.T., Bates, P.L., Falkingham, L., Piñuela, A., Rose, A., Freels, C., Kumagai, C., Libben, J., Smith, J. and Whitcraft, J., 2012, Dinosaur tracksites of the Paluxy River Valley (Glen Rose Formation, Lower Cretaceous), Dinosaur Valley State Park, Somervell County, Texas: 5th Jornadas Internacionales sobre Paleontología de Dinosaurios y su Entorno, Salas de los Infantes.

Fields, W., 1980, Paluxy River Explorations (1977-1979) revised edition. Privately published, 48 p.

Halbert, W.M., 1967, Geologic significance of Glen Rose dinosaur track. Unpublished Student Paper 627, Baylor University, 32 p.

Hawthorne, J.M., 1990, Dinosaur track-bearing strata of the Lampasas Cut Plain and Edwards Plateau, Texas: Baylor Geological Studies, Bulletin 49, p. 1-47.

Hayward, O.T., and Brown, L.P., Jr., 1967, Comanchean (Cretaceous rocks of Central Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section Publication 67-8, p. 31-48.

Kuban, G.J., 1989a, Elongate dinosaur tracks; *in* Gillette, D.D. and Lockley, M.G., eds., Dinosaur Tracks and Traces: Cambridge University Press, Cambridge, p. 57-72.

Kuban, G.J., 1989b, Color distinctions and other curious features of dinosaur tracks near Glen Rose, Texas; *in* Gillette, D.D. and Lockley, M.G., eds., Dinosaur Tracks and Traces: Cambridge University Press, Cambridge, p. 427-440.

Langston, W. and Pittman, J.G., 1987, Lower Cretaceous Dinosaur Tracks near Glen Rose, Texas; in Perkins, B.F., Langston, W., Jr. and Clarke, R.T., eds., Lower Cretaceous Shallow Marine Environments in the Glen Rose Formation: Dinosaur Tracks and Plants. Field Trip Guidebook, Southwest Section American Association of Petroleum Geologists, Dallas, TX, p. 39 – 69.

Lockley, M.G., 1991, Tracking Dinosaurs: A New Look at an Ancient World. Cambridge University Press, New York, p. 1-238.

Lozo, F.E and Stricklin, F.L., 1956, Stratigraphic notes on the outcrop basal Cretaceous, central Texas: Gulf Coast Association of Geological Societies Transactions, v. 6, p. 67-78.

Mayor, A., 2005, Fossil Legends of the First Americans. Princeton University Press, Princeton, p. 1-446.

Nagle, J.S., 1968, Glen Rose cycles and facies, Paluxy River Valley, Somervell County, Texas: Bureau of Economic Geology, Geological Circular 68, p. 1-25.

Perkins, B.F., 1979, Alternating marine and terrestrial environments in the Comanche Cretaceous lower Glen Rose Formation, Somervell and Hood Counties, Texas; *in* Perkins, B.F. and Langston, W., Jr. eds., Field Trip Guide, Lower Cretaceous Shallow Marine Environments in the Glen Rose Formation: Dinosaur Tracks and Plants: American Association of Stratigraphic Palynologists, 12th Annual Meeting, p. 9-37.

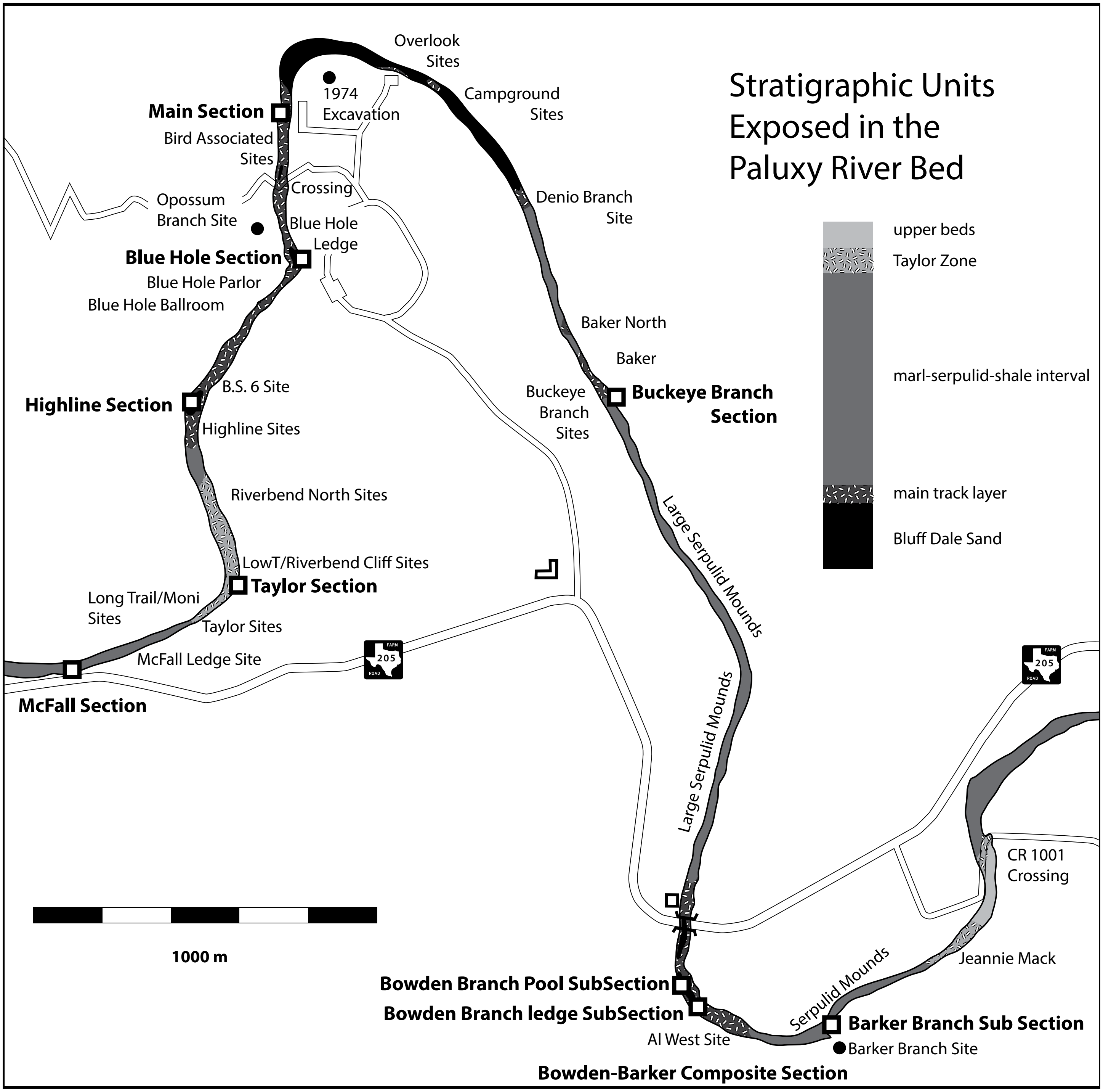

FIGURE 28. Generalized bedrock geology of the bed of the Paluxy River. See Figure 3 for key to colors.

Perkins, B.F., 1987, Alternating marine and terrestrial environments in the Comanche Cretaceous Lower Glen Rose Formation, Somervell and Hood Counties, Texas; *in* Perkins, B.F., Langston, W., Jr. and Clarke, R.T., eds., Lower Cretaceous Shallow Marine Environments in the Glen Rose Formation: Dinosaur Tracks and Plants. Field Trip Guidebook, Southwest Section American Association of Petroleum Geologists, Dallas, TX, p. 9-25.

Pittman, J.G., 1989. Stratigraphy, lithology, depositional environment, and track type of dinosaur track-bearing beds of the Gulf Coastal Plain; *in* Gillette, D.D. and Lockley, M.G., eds., Dinosaur Tracks and Traces: Cambridge University Press, Cambridge, p. 135-153.

Rodgers, R.W., 1967, Stratigraphy of the Glen Rose Limestone, Central Texas. IN Comanchean (Lower Cretaceous) stratigraphy and paleontology of Texas: Society of Economic Paleontologists and Mineralogists, Permian Basin Section Publication 67-8, p. 119-130.

Scott, R.W., 2007, Key bivalves of the Lower Albian Glen Rose Formation, Texas, U.S.A.; *in* Cretaceous Rudists and Carbonate Platforms: Environmental feedback. SEPM Special Publication No. 87, p. 247-252.

Scott, R.W., A.M. Molineux, H. Löser, and E.A. Mancini. 2007. Lower Albian sequence stratigraphy and coral buildups: Glen Rose Formation, Texas, U.S.A.; *in* Cretaceous Rudists and Carbonate Platforms: Environmental feedback. SEPM Special Publication No. 87, p. 181-191.

Shuler, E.W., 1937, Dinosaur tracks at the fourth crossing of the Paluxy River near Glen Rose, Texas. Field and Laboratory, v. 5, p. 33-36.

Ward, W.C. and Ward, W.B., 2007, Stratigraphy of the middle part of the Glen Rose Formation (Lower Albian), Canyon Lake Gorge, Central Texas, U.S.A.; *in* Cretaceous Rudists and Carbonate Platforms: Environmental feedback. SEPM Special Publication No. 87, p. 193-210.

Young, K., 1967, Comanche Series (Cretaceous, south central Texas: SEPM Permian Basin Section, Publication 67-8, p. 9-29.

APPENDIX 1

Locality list, including identification number, figure references, brief description, and latitude and longitude (decimal degree coordinates). These localities are cited by number in the figure captions.

264, Fig. 14A. Main Site Crossing. -97.818823, 32.25121

270, Figs. 6E, 14E. South end of Bird Site West Bank. -97.818726, 32.252376

273, Fig. 5A, 14C. North end of Bird Site. -97.818647, 32.25454

276, Fig. 15B. Overlook Section. -97.815016, 32.254489

277, Fig. 15C. Remnant of the main track layer exposed at base of Overlook Section. -97.813931, 32.254297.

281, Fig. 15E. Remnant of the main track layer in the Campground Area. -97.812652, 32.253159.

282, Fig. 16B. Island of the main track layer at the Denio Branch Site. -97.810591, 32.250933.

283, Fig. 16C. Denio Branch Tracksite. -97.810559, 32.250775.

284, Fig. 6D. Hardground bed in the Denio Branch Section. -97.810545, 32.250688.

285, Fig. 16D. Denio Branch Section. -97.810257, 32.250346.

287, Fig. 17B. Baker North Site. -97.809072, 32.247444.

289, Fig. 17F. Exposure of *Corbula* bed between the Baker North and Baker Sites. -97.808785, 32.246642.

290, Fig. 17C. Baker Tracksite. -97.808281, 32.245908.

291, Fig. 17E. Buckeye West Tracksite. -97.807787, 32.244977.

295, Fig. 6F. Lower steinkern marl in the Buckeye Branch Section. -97.806901, 32.244334.

296, Fig. 19C. Northernmost streambed exposure of the serpulid bed in the Serpulid Mound Region. -97.806463, 32.24305.

303, Fig. 11B. Highline Section. -97.821145, 32.245658.

304, Fig. 10B. *Diplocraterion* bed in the Riverbend North Area. -97.821185, 32.242371.

309, Fig. 8A. McFall Ledge Tracksite. -97.824493, 32.237328.

313, Fig. 7G. Large serpulid mound in the serpulid bed south of the Buckeye Branch Section. -97.806766, 32.243886.

314, Fig. 19B. transition from the Baker Area into the Serpulid Mound Region. -97.806483, 32.243221.

316, Figs. 7I, 19E. Stratigraphic Section SV-11 (Nagle 1968), with scattered serpulid mounds in the riverbed. -97.804871, 32.240134.

317, Fig. 20B. Upstream (northern) edge of serpulid shale outcrop. -97.803781, 32.239028.

319, Fig. 20C. Downstream (southern) edge of serpulid shale outcrop. -97.802894, 32.235763.

322, Fig. 7H. Serpulid-encrusted log. -97.803986, 32.232181.

323, Fig. 20E. Steinkern marl exposure upstream of Creation Evidence Museum. -97.804453, 32.23143.

324, Fig. 20F. Alluvium covered riverbed behind the Creation Evidence Museum. -97.804831, 32.229992.

325, Fig. 22C. Al West Site with main track layer in the riverbed and overlying stratigraphic section through the serpulid bed. -97.804406, 32.227161.

326, Figs. 7B, 22D. Part of Bowden Branch Section midway between the Al West Tracksite and the Mouth of Bowden Branch. -97.803971, 32.226921.

327, Fig. 22F. Part of Bowden Branch Section at eastern bank of Bowden Branch at the mouth of the tributary. -97.803569, 32.226648.

329, Fig. 23B. Barker Branch Stratigraphic Section. -97.799783, 32.226672.

347, Fig. 22B. Lower part of Bowden Branch Section where Bluff Dale Sand crops out above cutbank pool just upstream from the Al West Site/Bowden Branch mouth. -97.804947, 32.22778.

624, Fig. 10C. The Taylor Section in the cutbank of the LowT/Riverbend Cliff Area. -97.820231, 32.239897.

757, Fig. 11C. Dipping steinkern marls and *Corbula* bed upstream of Highline Tracksites. -97.822099, 32.243205.

759, Fig. 25F. *Diplocraterion* bed at the Jeannie Mack Site. -97.795501, 32.228722.

760, Fig. 23E. Taylor track layer mudcracks and probable track in the Barker Branch Tributary. -97.799771, 32.225865.

761, Fig. 23F-G. Possible tridactyl footprint on the surface of the *Diplocraterion* bed in Barker Branch. -97.799972, 32.22582.

763, Fig. 23H-J. Pool exposing sanstone and packstone marker beds in Barker Branch. -97.800594, 32.225054.